Overcoming the logistical challenges faced by the South African table grape phytosanitary cold treatment markets: A case study focusing on the Hex River and Berg River production areas

by

Marthinus Christiaan Pienaar

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Supervisor: Prof L.L. Goedhals-Gerber

December 2021

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ABSTRACT

New phytosanitary cold treatment markets are opening and established markets are transforming to cold treatment markets. This poses a risk to the South African table grape industry, which is losing excessive amounts of money each year because of not complying with each market protocol.

With the risks of markets closing, demand not being supplied on time and the preferred fruit quality not being achieved, it is crucial to research and propose potential solutions regarding the supply chain of the special cold treatment markets to preserve current and future markets. A standardised method must be implemented for the producers and exporters from the Hex River and Berg River production areas. This method must be more cost-effective, have shorter lead times from harvesting to supplying the customer and optimum cold chain management must be applied to eliminate temperature breaks.

A mixed method approach was used to conduct the research. Secondary qualitative data was the first form of data gathered for the research through a review of current literature. Primary qualitative data in the form of interviews and observations were used to aid the understanding of the quantitative data and answer the research questions. A self-administered questionnaire was sent to 31 role players in the table grape special cold treatment markets to determine the knowledge of the industry regarding exporting to these markets. The quantitative data source used was the insertion of 98 temperature monitoring devices into 24 pallets, divided into three concepts and eight trials.

The research identified methods that could be used to limit the logistical challenges faced in the Hex River and Berg River production areas, achieve shorter lead times and ensure optimum cold chain management.

The results showed that temperature breaks do occur from the packing stage until the fruit is loaded into the containers. The temperature breaks measured from the packing stage until the forced-air cooling stage are normal as the fruit is cooled down from packing. The temperature breaks measured from the last part of the forced-air cooling stage until the shipping stage were caused by mismanagement of the cold chain. Pallets were removed from forced-air cooling when the fruit was not cooled to the desired temperatures throughout the palletised pallet and in some cases the fruit was exposed to low temperatures of -1.5 °C for too long, causing fruit pulp temperatures of -1.5 °C and below.

This research benefits the South African table grape industry by identifying the logistical challenges faced in the Hex River and Berg River production areas, identifying methods to reduce these challenges and ensuring that sound logistical practices are implemented. Delivering the product from the farm to the consumer in the shortest time, at the lowest cost, in the best possible condition and maintaining cold chain integrity intact at all times.

Keywords

Cold chain, cold treatment, phytosanitary, Steri, temperature breaks

OPSOMMING

Nuwe fitosanitêre kouebehandeling markte word geskep en bestaande markte word omskep in kouebehandeling markte. Dit skep 'n risiko vir die Suid Afrikaanse tafeldruiwe bedryf, wat jaarliks buitensporige bedrae geld verloor omdat daar nie voldoen word aan die vereiste protokol vir elke mark nie.

Met die risikos van; markte wat toegang beperk of weier, aanvraag wat nie betyds gelewer word nie en vrugte wat nie aan die verkose kwaliteit voldoen nie, word dit deurslaggewend om oor die spesiale kouebehandeling markte navorsing te doen en potensiele oplossings voor te stel, wat huidige en toekomstige markte behoue sal laat bly.

Die navorsing is gedoen deur van 'n gemengde metode benadering gebruik te maak. Sekondêre kwalitatiewe data was die eerste vorm van data wat verkry was vir die navorsing, deur 'n bestudering van huidige literatuur beskikbaar in die betrokke veld. Primêre kwalitatiewe data in die vorm van onderhoude en observasies was gebruik om te help om die kwantitatiewe data te verstaan en vrae in die navorsing te beantwoord. 'n Self- geadministrateerde vraelys na 31 rolspelers in die spesiale kouebehandeling markte vir tafeldruiwe gestuur, om hul vlak van kennis aangaande die markte waarna hul uitvoer,vas te stel. Die kwantitatiewe data bron wat gebruik is, was die plasing van 98 temperatuur-moniterings toestelle in 24 palette, wat verdeel was in agt proewe, met elke proef onderworpe aan drie metings konsepte.

Die navorsing het metodes geïndentifiseer wat gebruik kan word om; die logistieke uitdagings in die Hex Rivier produksie area te beperk, aflewerings-tydlyne te verkort en koueketting bestuur te optimaliseer.

Die navorsing resultate het aangetoon dat daar verbrekings in die produk se temperatuur voorkom vanaf die verpakkings stadium totdat dit in die houers gelaai word. Die verbrekings in temperatuur wat gemeet word vanaf die verpakking stadium tot die geforseerde lugverkoeling fase is normaal omdat die vrugte verkoel word nadat die verpakking gedoen is. Die verbreking in temperatuur wat gemeet is vanaf die laaste fase van die geforseerde lugverkoeling proses tot die verskeepings fase was as gevolg van wanbestuur van die koueketting proses. Palette is verwyder uit die geforseerde lugverkoeling fasiliteit voordat dit volledig en dwarsdeur verkoel was tot die vereiste temperatuur. Gevalle is gevind waar die produk vir te 'n lang periode bloot gestel was aan lae temperature van minus 1,5 °C, wat temperature van minus 1,5 °C en laer in die vlees van die vrugte veroorsaak het.

Die navorsing hou voordele in vir die Suid Afrkaanse tafeldruiwe bedryf wat onder andere; die logistieke uitdagings in die Hex Rivier en Berg Rivier produksie areas indentifiseer, metodes indentifiseer wat die uitdagings kan verminder en so verseker dat gesonde en optimale logistieke praktyke geïmplementeer word. Dit sal gevolglik die voordele inhou van; lewering van die produk vanaf die plaas to by die verbruiker in die kortste moontlike tyd, teen die laagste koste, in die beste moontlike toestand en dat die intergiteit van die koueketting ten alle tye behoue bly.

Sleutelwoorde

Koueketting, kouebehandeling, fitosanitêre, Steri, temperatuur breke

ACKNOWLEDGEMENTS

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- Thembisele Mokheseng for technical assistance with the installation of data recorders.

DEDICATION

I dedicate this thesis and degree to my lovely wife and son. Thank you for enduring my prolonged absence from you as I worked on this arduous project …and to God be the glory!

ACRONYMS AND ABBREVIATIONS

°C	Degrees Celsius
AIFS	Australian Institute of Food Safety
CCS	Commercial Cold Store Code
CDC	Container Depot Code
CSCMP	Council of Supply Chain Management Professionals
CTCT	Cape Town Container Terminal
DAFF	Department of Agriculture, Forestry and Fisheries (now DALRRD)
DALRRD	Department of Agriculture, Land Reform and Rural Development
DAT	Delivery air temperature
FBO	Food business operators
FCM	False codling moth
FPEF	Fresh Producers Exporters' Forum
GDP	Gross Domestic Product
Genset	Generator set
IMO/ILO/UNECE	Code of Practice for Packing of Cargo Transport Units
NPPO	National Plant Protection Organisation
PHC	Packhouse Code
PPECB	Perishable Products Export Control Board
PUC	Production Unit Code
RMSSE	Root Mean Squared Scaled Error
SATI	South African Table Grape Industry
SCADA	Supervisory control and data acquisition
SO_2	Sulphur dioxide
SPS	Sanitary and phytosanitary
SSCG	Sustainable supply chain governance
Steri	Forced-air pre-cooling process, known in the industry as Steri.
TPT	Transnet port terminals
TRANS	Transport Operator Code
USDA	United States Department of Agriculture

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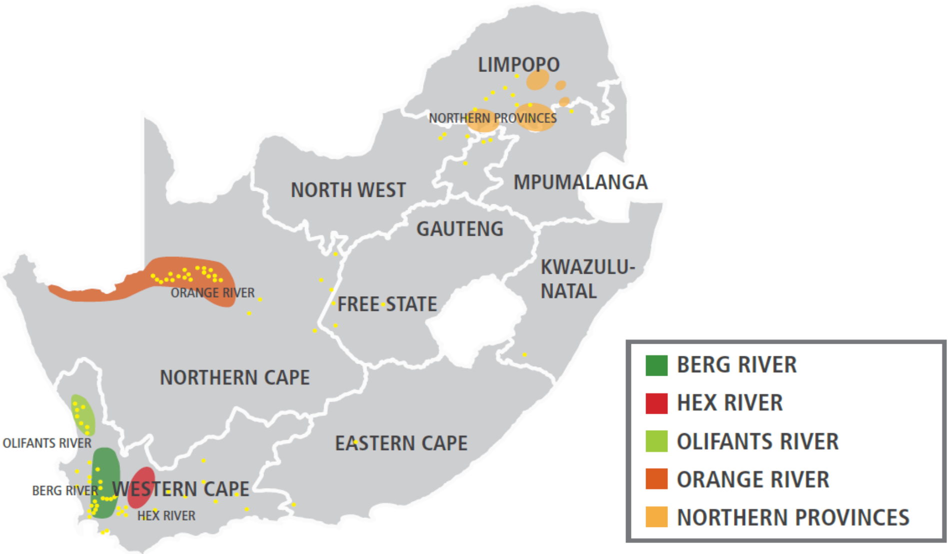
CHAPTER 1: INTRODUCTION

1.1 Introduction

Table grapes are grown and produced for fresh consumption by consumers. South Africa is the third-largest producer of table grapes in the southern hemisphere. Globally, South Africa is the fifth largest exporter of table grapes, with approximately 62.06 million 4.5 kg cartons of table grapes exported all over the world (Lombardt, 2018:3). The table grape industry employs approximately 74,820 people in the production units, besides all the other sectors that service the table grape industry in South Africa (Ferreira, 2019:6).

Table grapes produced a gross value of R7.1 billion in the 2015/2016 harvest season and R9 billion in the 2017/2018 harvest season. This is an increase of 70% over 10 production seasons, making this fruit commodity one of the most important deciduous fruits in South Africa (Mogala, 2019:4).

The production areas of table grapes in South Africa are indicated in Figure 1.1



Source: Lombardt (2018:8)

Ferreira (2019:6) lists the size in hectares (ha) of the five table grape production areas in South Africa as:

a) Northern Province: 2 589 ha

b) Orange River: 6 195 ha

c) Olifants River: 1 185 ha

d) Berg River: 5 210 ha

e) Hex River: 6 619 ha

1.2 Background

After the first attempt to export fruit from South Africa in 1880, the fruit industry evolved from a single-channel marketing organisation in 1946 to free enterprise marketing after deregulation in 1997 (Hurndall, 2005:6).

Improving and managing the supply chains within the fruit industry to deliver top-quality fresh produce all over the world is fundamental to the table grape export industry. Optimum cold chain management is essential for the table grape industry to ensure that the grapes endure the journey to the final destination, have a longer shelf life, are of optimal quality for consumers and expanding the South African table grape export market (Koegelenberg, 2019:1). The initial steps towards a cold chain process for the fruit export industry were introduced in South Africa in 1903 when the first pre-cooling stores were built in the Port of Cape Town. Fruit inspection, monitoring systems as well handling, cooling and storage techniques were developed and improved in 1958 (Hurndall, 2005:7).

Increasing business competition and more sophisticated consumer needs in the 1980s led to the realisation that product competitiveness is determined more through logistically arranged product supply chains than through individual firms operating in isolation (Pienaar & Vogt, 2012:9).

In 1926, the deciduous fruit producers in South Africa formed the SA Deciduous Fruit Exchange and in 1939 the Deciduous Fruit Board was officially formed and took over all exports under the single-channel scheme. After deregulation in 1997, the South African table grape producers formed their own commodity forum called the South African Table Grape Industry (SATI) (Hurndall, 2005:7). These forums were established to add value to the industry, having a direct influence on the value chain of SATI.

The Department of Agriculture, Land Reform and Rural Development (DALRRD), SATI and the Fresh Producers Exporters' Forum (FPEF) represent the table grape industry in accessing new markets, ensuring a good quality product being exported to meet market requirements and enforcing the rules to prevent markets from closing. Due to phytosanitary insect and plant health risks, some of the export markets are known in the industry as special markets. After the fruit has been passed by the Perishable Products Export Control Board's (PPECB) quality inspection, DALRRD inspectors do a phytosanitary inspection of the fruit. If the fruit passes the quality and phytosanitary inspection, the next step in the process is cold treatment, also known in the industry as Steri. Each special market has different cold treatment requirements. Table 1.1 shows the countries that are seen as special markets for SATI.

Table 1.1: Summary of the special market cold treatment container protocol

Country	Inspection	Cold Treatment Protocol
United States of America	PPECB & DALRRD	All fruit must be pre-cooled for 72 hours; in the last 24 hours, the fruit must be colder than -0.6 °C.
Japan	PPECB & DALRRD	All fruit must be pre-cooled for 72 hours to the target temperature of -0.5 °C.
China	PPECB & DALRRD	All fruit must be pre-cooled for 24 hours to the target temperature of -0.5 °C.
Israel	PPECB & DALRRD	All fruit must be pre-cooled for 72 hours to the target temperature of -0.6 °C.
Thailand	PPECB & DALRRD	All fruit must be pre-cooled for 72 hours to the target temperature of -0.6 °C.
India	PPECB & DALRRD	Land-based sterilsation; fruit must be pre-cooled and kept under 0 °C for 10 days, or 0.55 °C for 11 days, or 1.1 °C for 12 days.
Indonesia	PPECB & SGS	All fruit must be pre-cooled for a minimum of 12 hours to the target temperature of 0 °C.
Taiwan	PPECB	All fruit must be pre-cooled for a minimum of 12 hours to the target temperature of -0.5 °C.
Sri Lanka	PPECB	All fruit must be pre-cooled for a minimum of 12 hours to the target temperature of -0.5 °C.
Vietnam	PPECB & DALRRD	All fruit must be pre-cooled for a minimum of 12 hours to the target temperature of -0.5 °C.
Jordan	PPECB	All fruit must be pre-cooled for a minimum of 12 hours to the target temperature of 0 °C.

Source: PPECB (2020b:6)

The major export markets for South African table grapes are Europe and the United Kingdom. Currently, there is much focus on these markets because of false codling moth (FCM) interceptions in Europe. All fruit commodity industries, together with DALRRD and the PPECB, are working on preventative action plans to protect these markets.

Mpholo (2018:20) reports that the European officials sent a letter to DALRRD with a clear message that read:

> "It is important that the causes of the interceptions are investigated and that appropriate measures are taken now, to ensure that exports are free from harmful organisms and comply fully with EU phytosanitary requirements. It would be appreciated if your services provide a report on the outcome of the investigations and the corrective actions that have been taken, or planned, to prevent a recurrence, together with an updated system approach for FCM".

Cold treatment is an effective system approach that can be implemented to reduce the occurrence of FCM interceptions in Europe, but South Africa's cold storage facilities infrastructure is currently not able to handle high cold treatment volumes (Moore & Cronje, 2018:24).

1.3 Motivation and purpose of the study

The table grape industry has many logistical challenges to overcome. These challenges are often overlooked within the industry and are of vital importance during the daily operations when South Africa's table grape season is at its peak.

This research attempts to assist the Hex River and Berg River production areas with several issues. Firstly, it will assist producers and exporters to be more cost-effective in the cold chain, specifically focusing on the special and cold treatment markets. Secondly, it will eliminate possible delays in the transportation of the product due to paperwork or market requirements that are not in place. Thirdly, the research highlights aspects of the cold chain process that can be used by significant role players from the Hex River and Berg River to improve the quality of service and client satisfaction. Finally, it will equip the Hex River and Berg River production areas with the methods and information on how to standardise the supply chain and overcome their challenges during the table grape season.

1.4 Problem statement

There is a growing risk with new phytosanitary cold treatment markets opening and established markets transforming to cold treatment markets. SATI is losing excessive amounts of money each year because of non-compliance with each market protocol.

With the risks of markets closing, demand not being supplied on time and the preferred fruit quality not being achieved, it is crucial to research and propose potential solutions regarding the supply chain of the special cold treatment markets to preserve current and future markets.

Several studies have been conducted on temperature breaks in the cold chain of fresh produce. However, no studies have investigated the logistical challenges of the special cold treatment markets to create a standardised method of overcoming the challenges involved in these markets. This study identifies the challenges faced from registration, packing requirements, documentation, transport, phytosanitary inspections, the inspection points, cold storage facilities and cold treatment of table grapes originating from the Hex River production area. The study also addresses the logistical challenges faced and a standardised work method was created to overcome these challenges.

1.5 Research objectives

The primary objective of this research was to create a method to overcome the logistical challenges faced by the Hex River and Berg River producers in supplying high quality table grapes to the special cold treatment markets.

The method must be more cost-effective, have shorter lead times from harvesting to supplying the importer and the cold chain must always be intact to ensure high quality table grapes.

The objectives and related research questions are shown in Table 1.2.

Table 1.2: Research questions and related research objectives

Research Questions	Research Objectives	Addressed in Chapter
1. What are the main logistical challenges faced by the Hex River and Berg River production areas regarding the special cold treatment markets and how can the identified challenges be overcome?	1. Research and understand the special cold treatment markets. Understand the challenges the production area must overcome to meet the criteria of each special market.	Two; Four, Five and Six
2. How can the special cold treatment process be improved to achieve shorter lead times by complying with each protocol?	2. Implementing a method used by all producers and exporters in the Hex River production area to be more cost effective, shorten the lead times and ensuring better quality product at the end consumer.	Four, Five and Six
3. How can the process from harvesting to placing fruit under cold treatment be accelerated?	3. Research a breaching experiment to challenge the norm. The breaching experiment will be more cost effective, have shorter lead times and be more flexible to select shipping options.	Four, Five and Six
4. Do fluctuations in temperature occur, resulting in breaks in the cold chain?	4. Identify the temperature fluctuations and breaks to address the causes and to avoid these fluctuations and breaks in the future.	Four, Five and Six

Source: Compiled by the researcher for the purpose of this study

1.6 Research questions

The following research questions form the base of the research study.

a) What are the main logistical challenges faced by the Hex River and Berg River production areas regarding the special cold treatment markets and how can the identified challenges be overcome?

b) How can the special cold treatment process be improved to achieve shorter lead times by complying with each protocol?
c) How can the process from harvesting to placing fruit under cold treatment be accelerated?
d) Do fluctuations in temperature occur, resulting in breaks in the cold chain?

1.7 Conceptual framework

The conceptual framework of this study is depicted in Figure 1.2.

The framework illustrates the flow of the research, starting with a basic illustration of the cold sterilisation market supply chain.

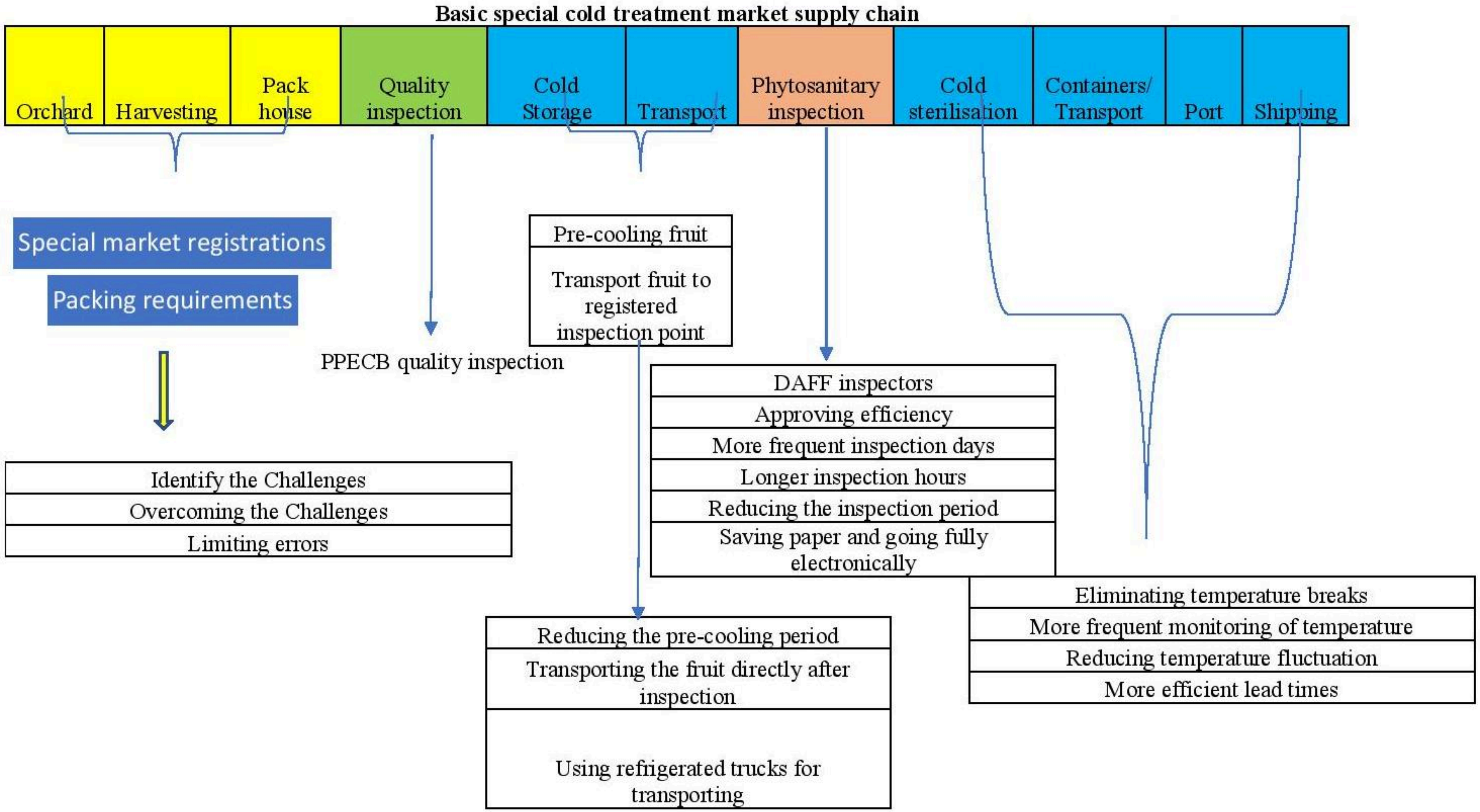


Figure 1.2: Conceptual framework

1.8 Structure of the thesis

Chapter 1

Chapter 1 introduces and provides the background to the research. Basic terms and concepts are clarified. The research problem, aim of the research and research objectives are outlined.

Chapter 2

This chapter reviews existing literature relevant to the topic under investigation, providing secondary qualitative data. The chapter summarises previous studies and explains definitions, statements and protocols set for the table grape phytosanitary cold treatment markets.

Chapter 3

Chapter 3 discusses the research design and methodology applied in this study. It explains the research approach to gathering the data necessary to conduct the research. The chapter covers planning, sampling, equipment, data collection and data analysis. It concludes with a discussion on the ethical principles considered for the study.

Chapter 4

This chapter analyses the survey and temperature data per concept. The results of the temperature trials are discussed and illustrated with tables and graphs.

Chapter 5

Chapter 5 interprets the results, graphs and tables discussed and illustrated in Chapter 4.

Chapter 6

Chapter 6 concludes the study. It discusses the achievement of the research objectives and highlights how the research questions were answered. Recommendations are made and suggestions for possible future research are provided.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Previous research and literature highlight the importance of the research topic and provide an understanding of the cold chain of table grapes exported to special markets. The first segment of the literature review is a broad overview of the South African fruit and table grape industry. Additional knowledge of the terms supply chain, logistics and how the cold chain forms part of the supply chain in the fresh produce industry is critical for the researcher to understand. Special markets and influential segments that have a direct influence on the table grape export industry are explained to provide an in-depth understanding of the industry.

2.2 The South African fruit industry

South Africa is well known globally as a producer and exporter of citrus, deciduous and subtropical fruits (Phaleng, Tshitiza, Ntombela & Lubinga, 2019:3). Approximately 90% of South Africa's fruit is exported while the remaining 10% is consumed locally or processed (Phaleng, 2017:2). South Africa was ranked the 10th largest exporter of fruit products in 2016 with a growth of 95.1% between 2007 and 2016 (Phaleng, 2017:3).

In 2018, the export of fresh fruit was approximately $3.7 billion, contributing 2.59% to South Africa's gross domestic product (GDP), a Rand value of approximately R74.1 billion (Conradie, 2019:12).

The fruit industry is the largest contributor, by value, to South African agricultural exports. The industry has a high job-multiplier effect and creates more than 400 000 jobs throughout the value chain (Uys, 2016:2).

Citrus is the largest fruit commodity being exported from Southern Africa and comprises oranges, lemons, grapefruit and soft citrus (Conradie, 2019:14). The second-largest fruit commodity being exported is deciduous fruit divided into three groups, namely stone fruit, pome fruit and table grapes (DALRRD, 2020:37). Stone fruit consists of peaches, plums, nectarines and apricots (Kruger, 2019:46). Pome fruit (apples and pears) is the largest deciduous fruit commodity being exported (DALRRD, 2020:39). Table grapes are the second largest deciduous fruit commodity and the third-largest fruit commodity overall exported from South Africa (Kruger, 2019:4).

The three biggest export destinations are Europe at 35.43%, Asia at 20.62% and the United Kingdom at 14.04% (DALRRD, 2020:19). Figure 2.1 illustrates the destinations of all fruit exported.

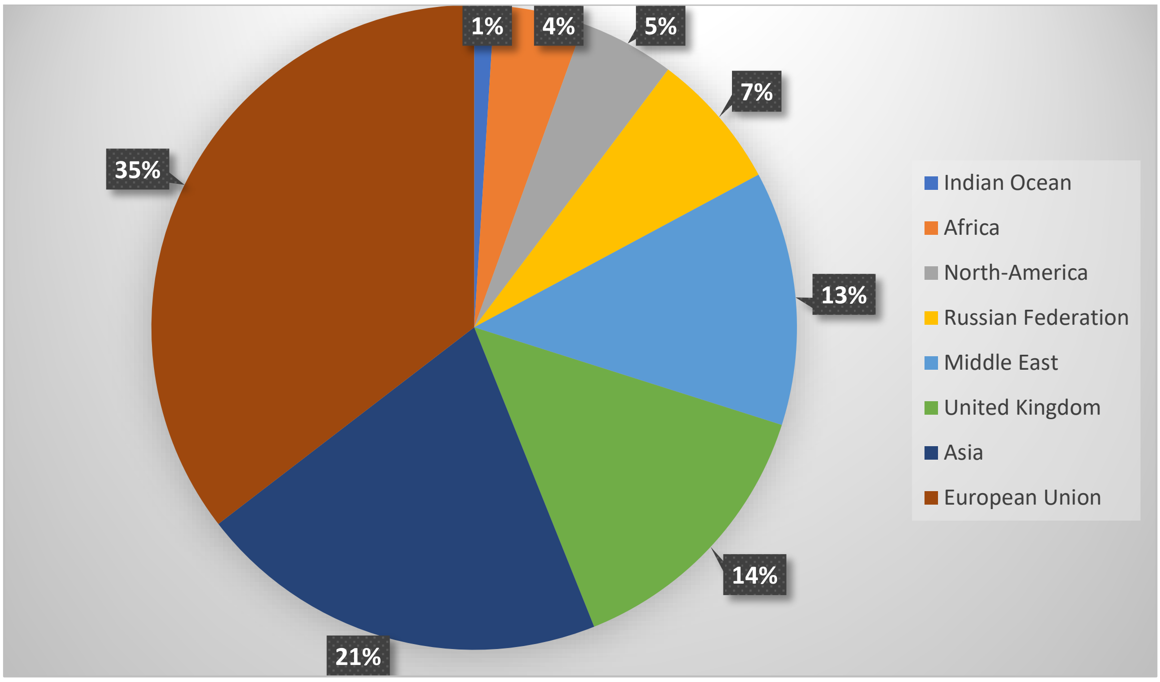


Figure 2.1: Export destinations for 2018/2019 season of all fruit commodities
Source: DALRRD (2020:19)

2.3 South African table grapes industry

South Africa is the third-largest producer of table grapes in the southern hemisphere, and globally, South Africa is the fifth largest exporter of table grapes, with approximately 62.06 million 4.5 kg cartons of table grapes exported all over the world (Lombardt, 2018:3). For the 2019/2020 season, 66.15 million 4.5 kg cartons of table grapes were inspected for export (Ferreira, 2020:3).

Globally, South Africa is the 10th largest producer of table grapes (Kisten, 2020:48). China is the largest producer and consumer of table grapes in the world, with 708 000 ha planted, producing an estimated 10.8 million tons (Zang, 2020:1). Chile is the largest table grape exporter, exporting approximately 645 000 tons (Zang, 2020:1).

Table grapes produced a gross value of R7.1 billion in the 2015/2016 harvest season and R9 billion in the 2017/2018 season, a 70% increase over 10 production seasons, making this fruit commodity one of the most important deciduous fruits in South Africa (Mogala, 2019:5). Table grapes are regarded as the most profitable fresh fruit to market per kilogram (Kisten, 2020:48).

For the 2019/2020 season, the table grape industry employed 78 670 people in the production units, an increase of 5.15% in employment over the 2018/2019 season in which 74 820 people were employed (Ferreira, 2019:6).

2.4 Hex River and Berg River production area

The Hex River production area is the largest, with 6 619 ha under table grape vineyards (Ferreira, 2019:3). It is approximately 85 kilometres from Cape Town (Pryke, 2005:330). The area creates work opportunities for 17 041 employees (Ferreira, 2019:41). The harvesting season starts at the end of December (week 51) and ends at the beginning of May (week 19) (Lombardt, 2018:41). The soil of this production area is sandy, moderately deep with swift infiltration and permeability of groundwater (Pryke, 2005:331). The area has a Mediterranean to semi-arid climate, with a winter rainfall that ranges between 240–320 mm per annum (Pryke, 2005:331).

There are 112 China-registered packhouses and 120 Vietnam-registered packhouses in the Hex River production area (DALLRD, 2020). There are not enough PPECB inspectors to have permanently at each packhouse facility (Mans, 2019).

The Hex River production season is illustrated in Figure 2.2.

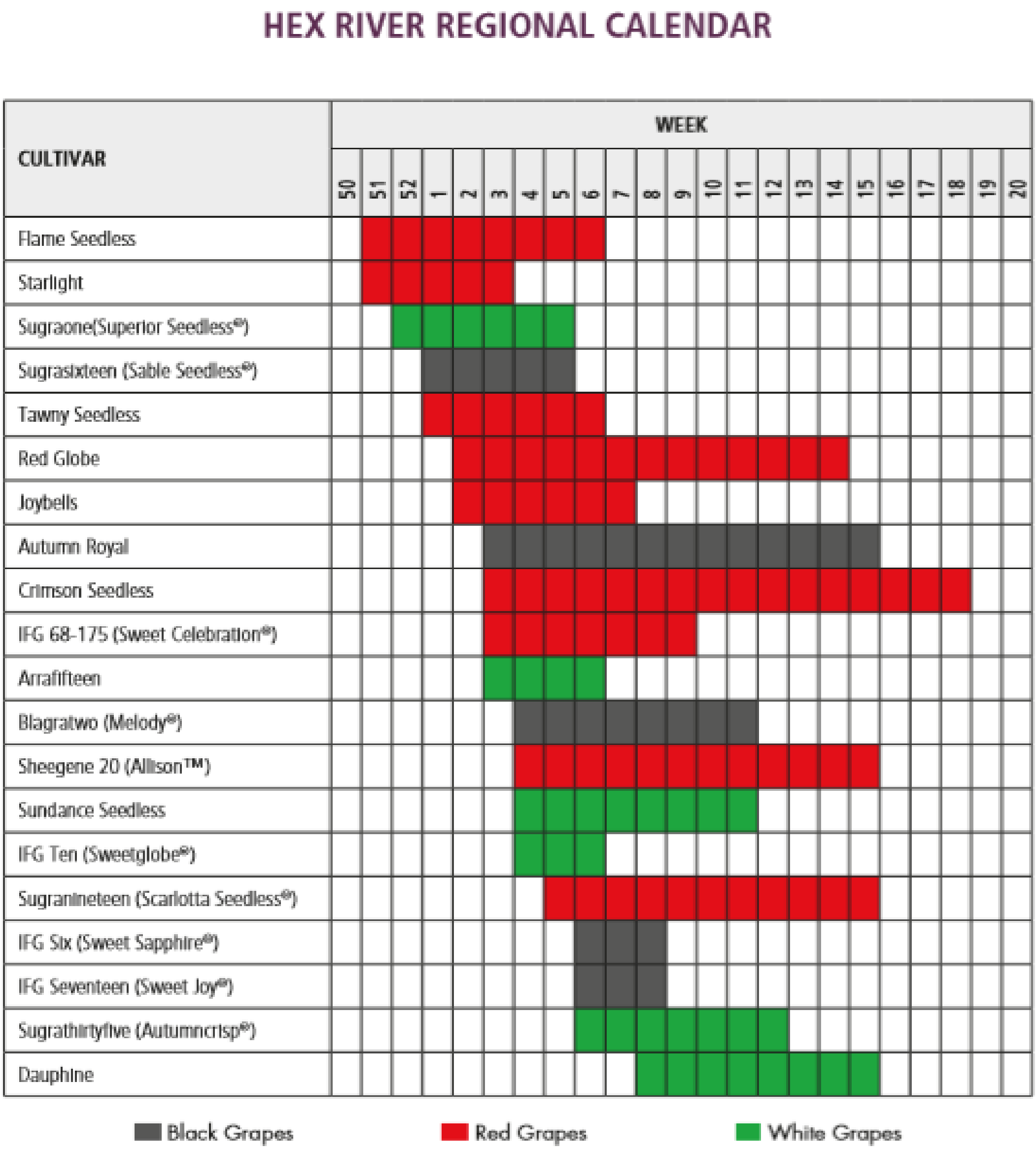


Figure 2.2: Hex River 2019 production calendar by cultivar 2019

Source: Ferreira (2019:43)

The Berg River production area is the third largest, with 5 210 ha under table grape vineyards (Ferreira, 2019:6). The area creates work opportunities for 19 804 employees (Ferreira, 2019:37). The harvesting season starts at the end of December (week 48) and ends at the beginning of May (week 19) (Ferreira, 2019:37). The Berg River production season is illustrated in Figure 2.3.

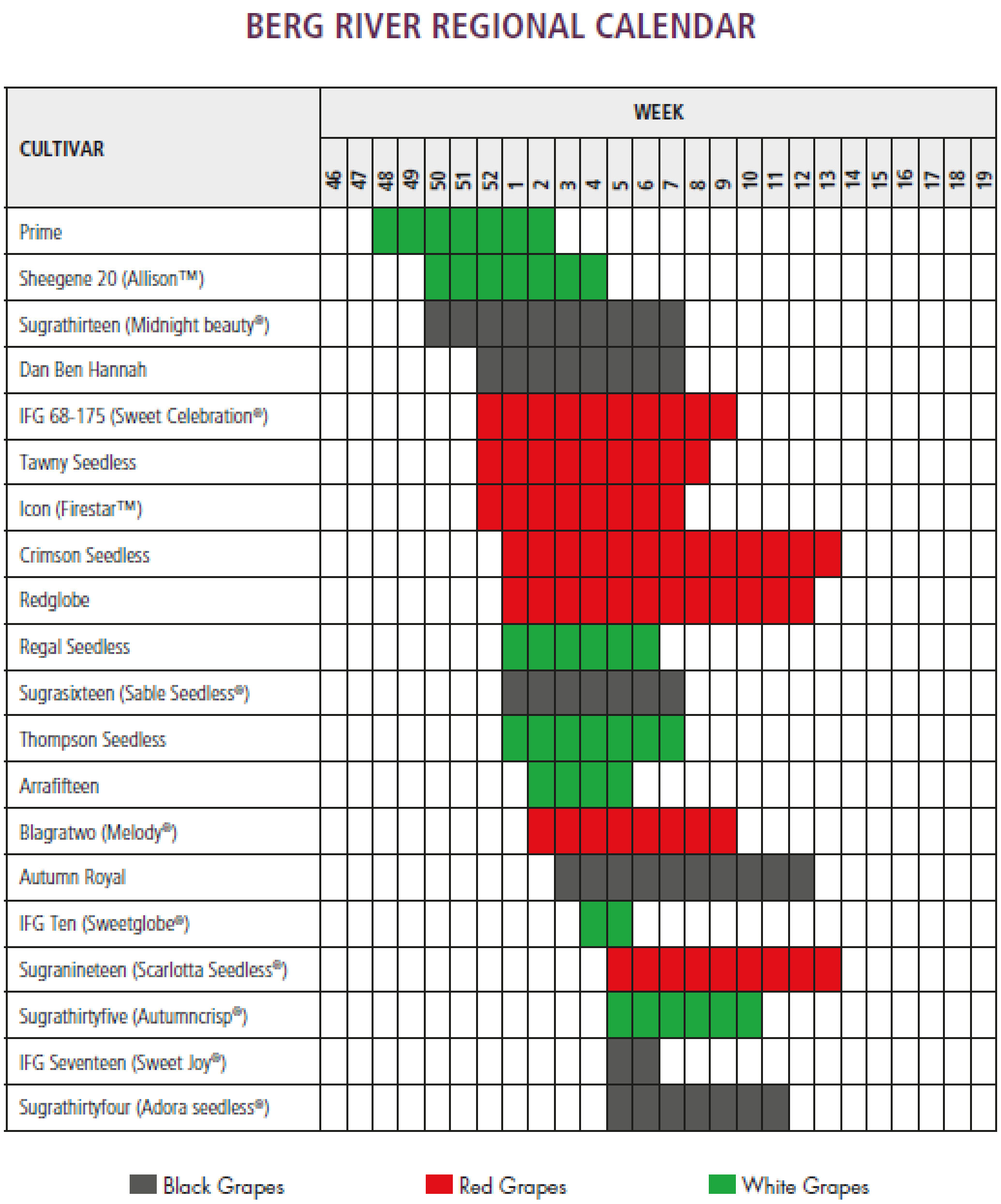


Figure 2.3: Berg River 2019 production calendar by cultivar 2019

Source: Ferreira (2019:39)

The following fees are supplied to give an indication on the cost involved (Crous, 2019): The average cooling, handling and seven day stoage fee in the Hex River production area, all included, is R533.00 per pallet and the Berg River production area is R465.00 per pallet.

The steri, cooling, handling and storage fee in the Berg River and Cape Town area, all included, is R730.00 per pallet.

2.5 Supply chain

A supply chain consists of all the stages in fulfilling a customer's request. It includes the manufacturers, suppliers, transporters, warehouses (cold storage facilities), retailers and the customers themselves. The five major supply chain drivers are production, inventory, location, transportation and information (Hugos, 2011:20). Supply chain management focuses on the total logistics costs and not on individual costs, representing some form of cost-saving (de Villiers et al., 2017:6). The Council of Supply Chain Management Professionals (CSCMP, 2020:6) defines supply chain management as "…encompasses the planning and management of all activities involved in sourcing and procurement, conversion and all logistics management activities."

Figure 2.4 illustrates the fresh fruit export supply chain, from breeding the plant material to the end consumer.

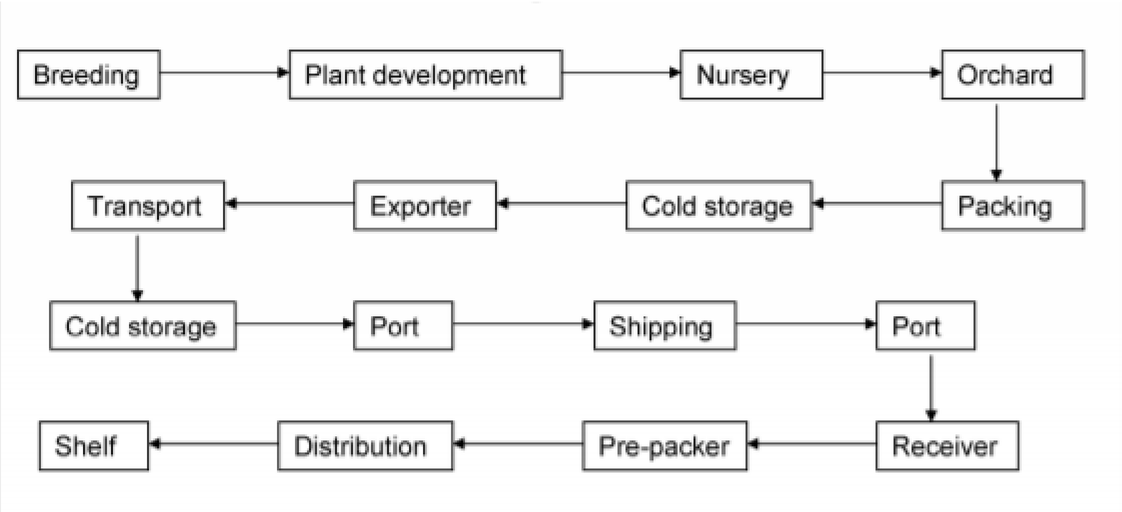


Figure 2.4: Supply chain of the fresh produce industry

Source: Van Dyk and Maspero (2004:59)

2.6 Logistics

The word 'logistics' was first used in 1836, meaning the planning, handling and implementation of personnel, related material, facilities and other factors. Logistics refers to all means and methods of organising service, especially the flow of materials before, during and after production (Pienaar & Vogt, 2012:8). The objective of good logistical practices is to deliver finished goods or raw materials, in the correct quantities, on-demand, at the desired location and in the preferred condition at the lowest cost (Bowersox, 1976:10). The segment of the supply chain that plans, implements and controls the efficient forward and reverse flow and storage of goods, services and related information between the point of origin and final consumption to meet the customers' requirements is known as logistics management (de Villiers, Nieman & Nieman, 2017:15). The purpose of logistics in the fresh produce industry is to get the product from the farm to the consumer in the shortest time, at the lowest cost, in the best possible condition and maintaining cold chain integrity intact at all times (O'Byrne, 2016:1).

2.7 Perishable nature and shelf life of table grapes

The respiration rate of table grapes is very low, causing the grapes not to ripen after harvesting. Table grapes are, therefore, classified as non-climacteric fruit (Tripathi, Pandey, Malik & Kaul, 2016:28). It is, therefore, necessary to harvest the table grapes at an optimally ripe stage. The sugar content must be high and acidity low. High acidity and low sugar levels influence the shelf life (Hurndall, 2005:11). Non-climacteric fruits have a shorter shelf life than climacteric fruits, as non-climacteric fruits begin to decay after the fruit has been harvested (Fedeli, 2019:40).

Respiration can be slowed down by cooling; low temperatures protect quality attributes such as aroma, berry texture, nutrition and deterioration of flavour (du Plessis, 2003:4). The current best practice is to get the grape pulp temperature to 10 °C within 12 hours after packing (Valentyn, 2007:2)

Table grapes are stored and shipped at a supply air temperature of -0.5 °C and relative humidity of 95% (Hurndall, 2005:9). Relative humidity refers to the maximum amount of moisture that air can hold before condensation. The air within the tissue of fruit ranges between 97% and 99%. The water in the fruit evaporates, causing deterioration of the fruit if the storage relative humidity is too low. Any temperature rise will cause moisture to condense on the grapes, the stems will dry out and the risk of decay will increase (Hurndall, 2005:10). Decreasing or increasing temperature may cause condensation to take place (Brunner, 2014:50).

Optimal cold chain management is necessary to increase the shelf life and maintain the preferred quality of table grapes. It is important to always keep the cold chain integrity intact. Table grapes are extremely perishable due to a post-harvest fungal rot caused by the fungal pathogen, *Botrytis cinerea*. By controlling and managing the cold chain, the fungal growth can be contained (Haasbroek, 2013:17).

Any temperature break at any stage of the cold chain will result in a reduction in the shelf life of the product (Valentine & Goedhals-Gerber, 2017:2). The longer the length of the break and the higher the temperature reached, the more severe the reduction in quality. Several small breaks will have the same negative effect on fruit quality as one large break (Freiboth, Goedhals-Geber, van Dyk & Dodd 2013:3).

2.8 Cold chain

A cold chain is a supply chain of temperature-sensitive products (Ruiz-Garcia, 2010:2). A cold chain can be described as "the seamless movement of fresh, chilled or frozen products, from the production area to the market, through various storage and transport mediums, without any change in the optimum storage temperature and relative humidity" (PPECB, 2019:6).

Temperature control is the key point in cold chain operations, from production to consumption in a safe, wholesome and good quality state. Successful cold chains call for automated and efficient monitoring and control of all operations (Ruiz-Garcia, 2010:4). The cold chain is a necessary and mandatory process in the export chain of fresh produce because time and temperature are key factors throughout the chain to ensure a better quality of produce (van Dyk & Maspero, 2004:58). Small temperature variations can influence the shelf life of fresh produce and its value, therefore, any break in the cold chain at any stage along the supply chain will reduce the shelf life of the produce (Goedhals-Gerber, Haasbroek, Freiboth & van Dyk, 2015:3).

A temperature break is defined as any time when the temperature reading rises above the optimum temperature at which the product must be kept during the cold chain (Freiboth et al., 2013:2). In previous studies, a temperature break was defined as any time in the data when the temperature reading measured 2 °C and warmer or cooled down to -1.5 °C or below for 90 minutes or longer (Goedhals-Gerber, Stander & van Dyk, 2017:372). A temperature spike is defined as any time when the temperature rises but does not follow the criteria of a temperature break (Conradie, 2019:51).

Figure 2.5 illustrates a generic table grape cold chain used for interpretation purposes.

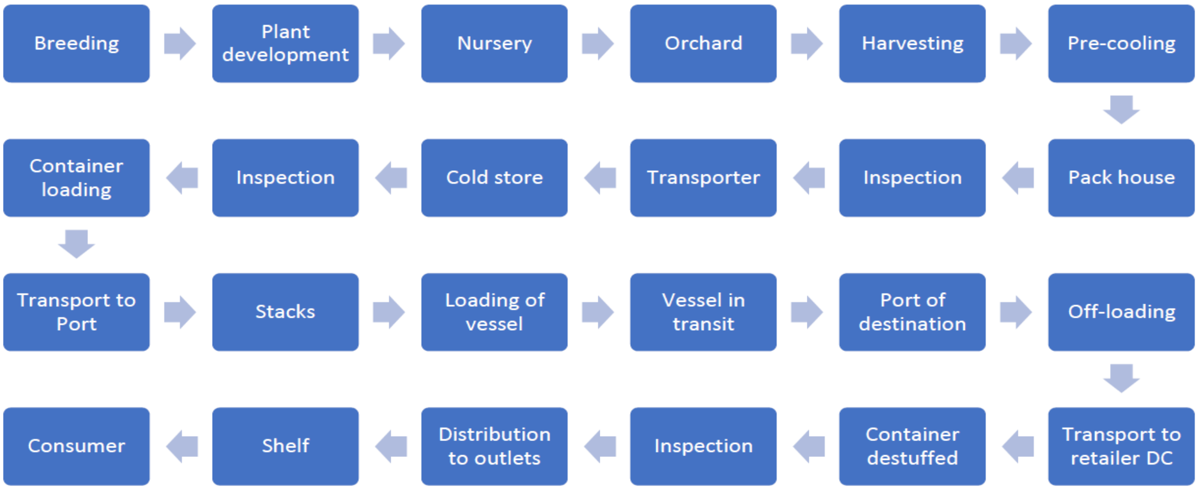


Figure 2.5: Generic table grape cold chain flow diagram

Source: Fedeli (2019:28)

Optimum cooling and storage preserve table grape quality by limiting the growth of decay-producing microorganisms, restricting enzymatic and respiratory activity, inhibiting water loss and reducing ethylene production (Ezeike & Hung, 2009:531). Maintaining low temperatures minimises the defects of weight loss, stem browning, softening of berries, shattering and decay (Ngcobo, 2008:15). The disorders can be reduced and controlled by reducing the temperature of the grapes from field temperature to 0 °C as fast as possible after harvesting (Freiboth et al., 2013:2). Therefore, the current recommended best practice is to place grapes under forced-air cooling within six hours after packing and the temperature of the grapes should be reduced to -0.5 °C within 48 hours (Hurndall, 2005:10).

Defining the Standard Cold Chain of Table Grapes

To ensure excellent fruit quality on arrival at the end consumer, four main pillars must be considered, namely (a) Fruit quality during harvesting, (b) Forced-air cooling, (c) SO_2 gasification and application, and (d) Correct loading in reefer containers (Luchsinger, 2015:1). These four pillars have a direct impact on the cold chain of table grapes. It is important to understand the cold chain of table grapes to understand this research study.

Figure 2.6 indicates the three vital aspects that form the base of the cold chain of table grapes.

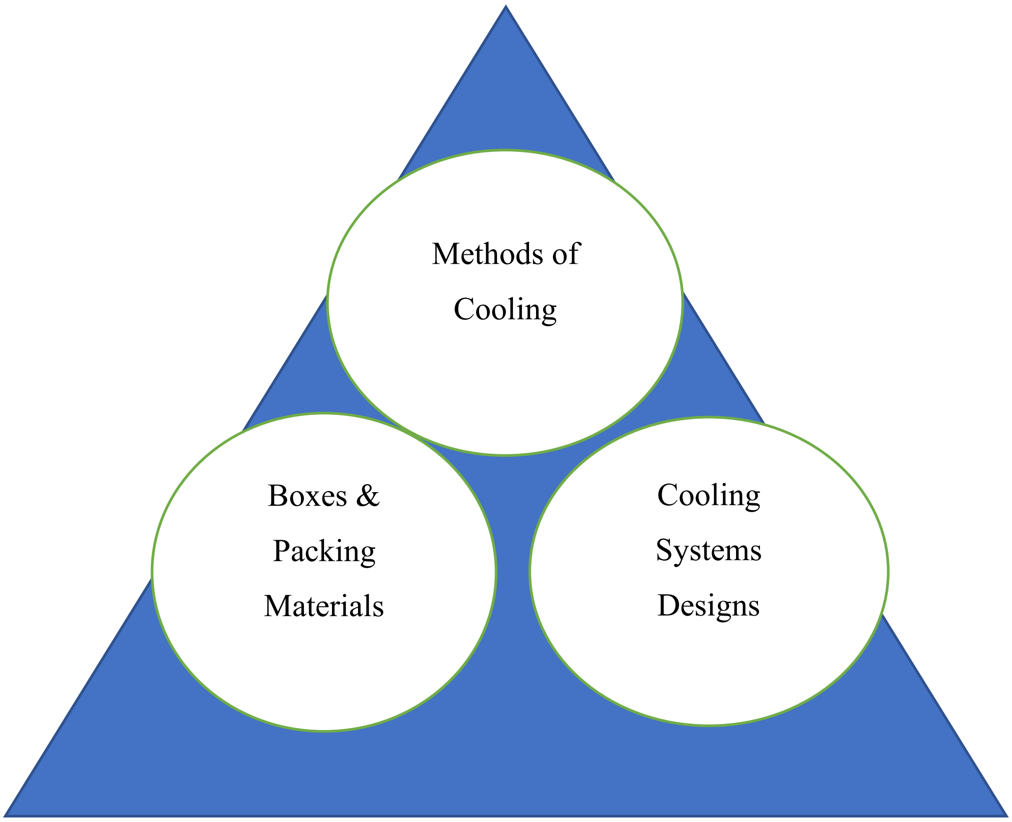


Figure 2.6: The cooling triangle

Source: Luchsinger (2015:2)

2.8.1 Harvesting

Harvesting of grapes is the initial stage of the cold chain, as grapes are freshly picked from a vineyard on a farm. Early harvesting of grapes to minimise field heat is recommended (Ezeike & Hung, 2009:519). The sugar to acid ratio of the fruit during harvesting is important as fruit with a lower sugar content is more sensitive to cold damage (Luchsinger, 2015:1). Harvested grapes must be stored in a shaded area until the grapes are transported to the packing facility (Luchsinger, 2015:1).

Grapes are harvested into grates and stored in the shade of the vineyards before the grapes are transported to a cooled or refrigerated room, usually at the packing facility (Fedeli, 2019:63).

The shaded storage process is illustrated in Figure 2.7.

Figure 2.7: Grapes being stored in the shade before being transported by tractor
Source: Jansen (2019:1)

Fruit is transported to the cooled or refrigerated room, usually at the packing facility using tractors or small flatbed trucks; transport should take place as soon as possible after the harvest of grapes (Ortmann, 2005:18).

The cooled or refrigerated room removes the field heat by a method known as room cooling (PPECB, 2020:5). Cooling practices used to remove field heat before the packing process begins are known as pre-cooling; room cooling is the most applied method used for pre-cooling. The room setpoint used for pre-cooling should be above dew point temperature, which is between 15–18 °C (Haasbroek, 2013:20).

2.8.2 Packing of grapes

In South Africa, packaging takes place in a specially designed facility called a packhouse. All packhouses must be registered for each special market before grapes may be packed for special cold treatment markets (Department of Agriculture, Forestry and Fisheries [DAFF], 2010:3).

Packing operations include a means of removing foreign objects, sorting to remove substandard fruit, sorting into selected size categories, inspecting samples to ensure that the fruit meets the specified standard of quality and packing for supplying the relevant markets or customers (Shewfelt & Prussia, 2009:11).

A modern and typical Hex River packhouse is shown in Figure 2.8.

Figure 2.8: Packhouse in the Hex River
Source: Viljoen (2019:2)

The best practice is to maintain the temperature of between 15–18 °C during the packing process, by temperature controlling the packing facility (Luchsinger, 2015:1).

Cooling fans are used to cool the packhouse environment to under 18 °C, which are indicated in Figure 2.9.

Figure 2.9: Cooling fans to control temperature in the packhouse
Photo credit, Researcher, 2020

Most packhouses in the Hex River production area send the finished packed product on pallets loaded onto small-unrefrigerated flatbed trucks to a cooperative commercial cold storage facility (Ortmann, 2005:18).

An example of these small-unrefrigerated flatbed trucks is indicated in Figure 2.10.

Figure 2.10: Small flatbed truck, delivering packed fruit to cold storage facility
Source: Modderdrift (2019:2)

2.8.3 Forced-air cooling

The current practice is to get the grape pulp temperature to 10 °C within 12 hours after packing and then to the desired 0.5 °C within 48 hours (Valentyn, 2007:2). Forced-air cooling is a fast-cooling method, four to ten times faster than conventional room cooling, by causing cold air to come into direct contact with the warm product. The heat of the product is transferred to the surrounding air through forced convection (Rao, 2015:75). To create forced convection, palletised fruit is placed on either side of a suction fan; all open spaces are covered with canvas to create an air plenum tunnel (Rao, 2015:75). The suction fan creates low air pressure within the tunnel, cold air from the room moves through the ventilation holes in the cartons toward the low-pressure zone, removing heat from the fruit (Rao, 2015:76).

A basic forced-air cooling tunnel is illustrated in Figure 2.11.

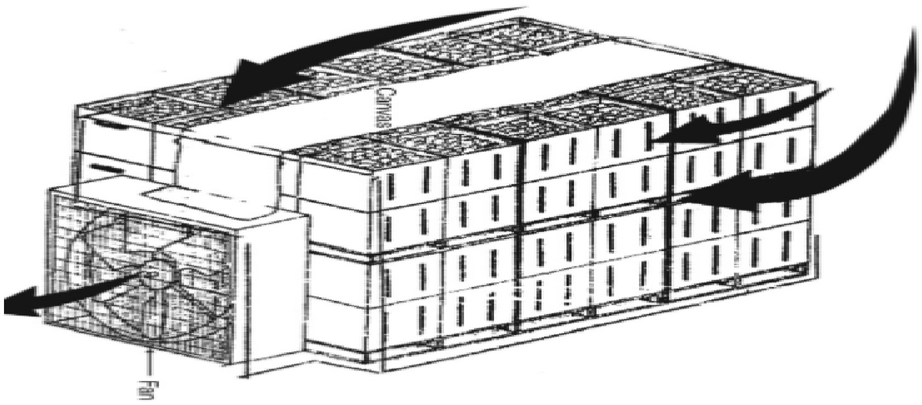


Figure 2.11: Forced-air cooling tunnel
Source: Rao (2015:76)

It is important to close all open areas with canvas to ensure that cold air moves through the product, to avoid hot spots and uneven cooling of the product in the tunnel (Rao, 2015:76).

Fruit is transported to registered special market inspection point cold storage facilities using refrigerated trucks that deliver a supply air of 0.0 °C or -0.5 °C (Ortmann, 2005:18).

Step-down cooling is a new procedure used in forced-air cooling. No documented research could be found regarding the step-down cooling of table grapes. The procedure was first introduced in the citrus industry and used to ensure gradual temperature reduction to reduce chilling injuries (McGlashan & du Plessis, 2017:2). The first step in the procedure is to set the delivery air temperature (DAT) to 15 °C to achieve uniform pulp temperatures. As soon as uniform pulp temperatures have been reached, the DAT will be decreased. There should always be a 2 or 3 °C difference between the pulp temperatures and DAT (McGlashan & du Plessis, 2017:3).

An example of the step-down cooling DAT changes as per pulp temperatures is illustrated in Table 2.1.

Table 2.1: Step-down cooling temperatures

Step-down Cooling		
DAT °C	**Pulp Temperature °C**	**Action**
15	18	Change DAT to 12 °C when pulp temp reaches 18 °C
12	14	Change DAT to 9 °C when pulp temp reaches 14 °C
9	11	Change DAT to 6 °C when pulp temp reaches 11 °C
6	8	Change DAT to 4 °C when pulp temp reaches 8 °C
4	6	Change DAT to 1 °C when pulp temp reaches 6 °C
1	4	Change DAT to -1.5 °C when pulp temp reaches 1 °C
-1.5	1	May not change setpoint colder than -1.5 °C
-1.5	-1	May not change setpoint colder than -1.5 °C

Source: McGlashan and du Plessis (2017:3)

2.8.4 Storage

Desired supply air temperature in the cold storage room is -0.5 °C with a relative humidity of 90–95% (Henning & Chetty, 2020a:1).

Table 2.2 indicates the table grapes' compatibility to reach an optimum shelf life of up to 180 days after harvesting.

Table 2.2: Compatibility to reach optimum shelf life for table grapes

Temperature	**Relative Humidity**	**Shelf life (days)**
0 °C –2 °C	85–95%	56–180

Source: Ezeike and Hung (2009:524)

Export grapes may only be stored for 21 days. After day 21 days, a PPECB re-inspection is necessary if the grapes are still to be exported. There are no limitations to the number of storage days for grapes going to the local market (PPECB, 2019b:5).

2.8.5 Cold treatment

The global fresh produce industry introduced cold treatment to prevent and monitor pests and disease during the trade of fresh produce to international markets (Mathaba, 2012:5). Cold treatment eliminates pests and diseases. Cold treatment is mainly used to prevent the spread of fruit fly and false codling moth during international trade (United States Department of Agriculture [USDA], 2007:7).

Only cold storage facilities that have been certified by the PPECB may handle cold treatment products (Henning & Chetty, 2020b:1). All forced-cooling tunnels used for cold treatment require a remote fruit pulp temperature monitoring system that monitors the fruit pulp and stores the data for a minimum of two years (PPECB, 2008:11). Each forced-cooling tunnel registered to handle cold treatment products must have a minimum of three pulp sensors, two on the inside of the tunnel and one on the outside face of the tunnel (Henning, 2019b:5).

The initial step of the treatment is to get the fruit pulp temperature below the required temperature as per each protocol. Each market has a different protocol to ensure that the required temperature is reached. The pre-cooling tunnel may only be opened or breached when the authorised PPECB inspector gives the go-ahead to load the container. The pallets are loaded directly from the tunnel into the container and loading must be completed within 40 minutes (Henning & Chetty, 2020c:8).

The second step in the treatment is the loading of the container. Before loading can take place, the cold storage facility must supply the authorised PPECB inspector with a physical printout of the fruit pulp temperature of the sensors for the required hours as per each protocol (Henning & Chetty, 2020c:8). Containers must be pre-cooled before being loaded. It is advisable to turn the refrigeration system of the container on 12 hours before loading (Henning & Chetty, 2020c:8). A generator set (Genset) is required to maintain the pre-cooling of the container before loading. During loading, the refrigeration system is switched off and after loading, the Genset is turned on for the refrigeration system to be switched on again (Henning & Chetty, 2020c:9). As soon as the container has been loaded, the first day of the cold treatment protocol starts. Every special cold treatment market protocol differs. Authorised and trained PPECB technical personnel supervise the cold treatment procedure and insert the on-board probes where necessary as per each cold treatment market protocol (Henning & Chetty, 2017a:6). A Genset is a device that generates electricity. They are installed on the trailers carrying the special cold sterilisation market containers. The Genset supplies electricity to the refrigeration system of the reefer container by being plugged into the Genset power outlet (Haasbroek, 2013:125).

The special cold treatment markets identified for this research were China and Vietnam. The reason for this was that the Chinese cold treatment market was trialled from a previous 72-hour protocol to a 24-hour protocol and the Vietnamese market became a cold treatment market in December 2019.

The various cold treatment protocols are indicated in Appendix C.

2.8.5.1 China

All fruit must be forced-air pre-cooled to a temperature below -0.5 °C and above -1.2 °C (Henning & Chetty, 2017be:2). The protocol used to be for 72 hours but has been amended to a minimum of 24 hours and the fruit must be below -0.5 °C for the last 6 hours (Henning & Chetty, 2017b:2).

The cold storage facility must supply the authorised PPECB inspector with a physical printout of the fruit pulp temperature of the tunnel sensors for the required 24 hours as per protocol (Moelich & Henning, 2019:2). Each forced-air cooling tunnel must be equipped with a minimum of two pulp sensors on the inside of the tunnel and one pulp sensor on the outside (Henning, 2019b:5).

The pre-cooling tunnel may only be opened or breached when the authorised PPECB inspector gives the go-ahead to load the container. The pallets are loaded directly from the tunnel into the container and loading must be completed within 40 minutes (Henning & Chetty, 2017b:8).

The container thermostat is set to control the delivery of air at -1.0 °C with the vents of the container kept closed (PPECB, 2020:4). Only containers may be used for exporting grapes to China. No conventional shipments are allowed (Department of Agriculture [DOA], 2007:10). The container must be equipped with three USDA-approved temperature monitoring fruit pulp sensors that record temperature data every hour (Henning & Chetty, 2017b:5).

Containers must be pre-cooled before being loaded. It is advisable to turn the refrigeration system of the container on 12 hours before loading (Henning & Chetty, 2017b:9). A Genset is required to maintain the pre-cooling of the container before loading. During loading, the refrigeration system must be switched off and after loading, the Genset must be turned on for the refrigeration system to be switched on again (Henning & Chetty, 2017b:8).

Sensor number 1 must be inserted into the top layer of fruit on the top right corner of the first pallet loaded into the container on the left-hand side. Sensor number 2 must be inserted into the fruit in the second last pallet row from the door on the left-hand side, 1.5 metres from the door, at half the height of the palletised pallet (pallet number 18) on the right-hand side of the pallet. Sensor number 3 must be inserted into the fruit on the second last pallet row from the door on the left-hand side, 1.5 metres from the door, at half the height of the palletised pallet (pallet number 18) on the left-hand side of the pallet (Henning & Chetty, 2017b:5).

An illustration of the positioning of the on-board probe sensor is indicated in Figure 2.12.

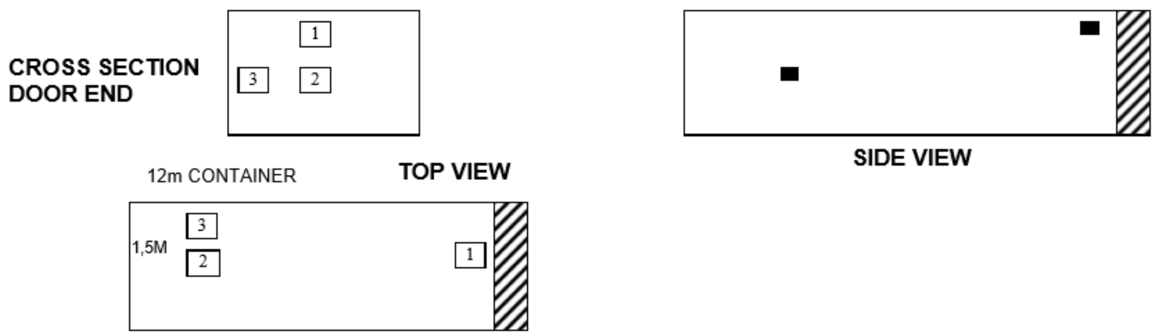


Figure 2.12: Sensor positioning in the container for China
Source: Henning and Chetty (2017b:6)

Authorised PPECB technical personnel supervise the loading process and insert the on-board fruit sensors into the fruit as per special market protocols. The tip of the sensor must not extend beyond the fruit (Henning & Chetty, 2017b:5).

The temperature measured by the on-board sensors may not exceed 0.8 °C for 20 days, known as the on-board sterilisation process. After 20 days with a pulp temperature of 0.8 °C or colder, the sterilisation protocol is completed and step-up temperature options may be considered by the exporter (PPECB, 2020:5).

2.8.5.2 Vietnam

Vietnam is the newest cold treatment protocol market. The market changed to cold treatment in December 2019 (DALRRD, 2019a:2). Before this, the fruit was loaded without cold treatment. Due to it being a new cold treatment protocol market, the China protocols are used as a benchmark in loading to this market (PPECB, 2020:4).

All fruit must be force cooled to the target temperature of -0.5 °C at the cold storage facility where the container will be loaded; this is known as the land-base pre-cooling Steri process (PPECB, 2020:4). Before loading can take place, the cold storage facility must supply the authorised PPECB inspector with a physical printout of the fruit pulp temperature of the sensors. The PPECB inspector can request up to a 12-hour printout (PPECB, 2020:6). Each forced-air cooling Steri tunnel must be equipped with a minimum of two pulp sensors on the inside of the tunnel and one pulp sensor on the outside of the tunnel (Henning, 2019b:5).

The container thermostat is set to control the delivery air at -1 °C with the vents of the container kept closed (PPECB, 2020:4). The container must be equipped with three USDA-approved temperature monitoring fruit pulp sensors that record temperature data every hour (Henning & Chetty, 2020a:4).

Containers must be pre-cooled before being loaded. It is advisable to turn the refrigeration system of the container on 12 hours before loading (Henning & Chetty, 2020a:7).

A Genset is required to maintain the pre-cooling of the container before loading. During loading, the refrigeration system must be switched off and after loading, the Genset must be turned on for the refrigeration system to be switched on again (Henning & Chetty, 2020a:8).

Sensor number 1 must be inserted into the top layer of fruit on the top right corner of the first pallet loaded into the container on the left hand side. Sensor number 2 must be inserted into the fruit of the second last pallet row from the door on the left-hand side, 1.5 metres from the door, at half the height of the palletised pallet (pallet number 18) on the right-hand side of the pallet. Sensor number 3 must be inserted into the fruit of the second last pallet row from the door on the left-hand side, 1.5 metres from the door, at half the height of the palletised pallet (pallet number 18) on the left-hand side of the pallet (Henning & Chetty, 2020a:5).

The on-board probe sensor positioning is indicated in Figure 2.13, to supply the reader with a visual illustration.

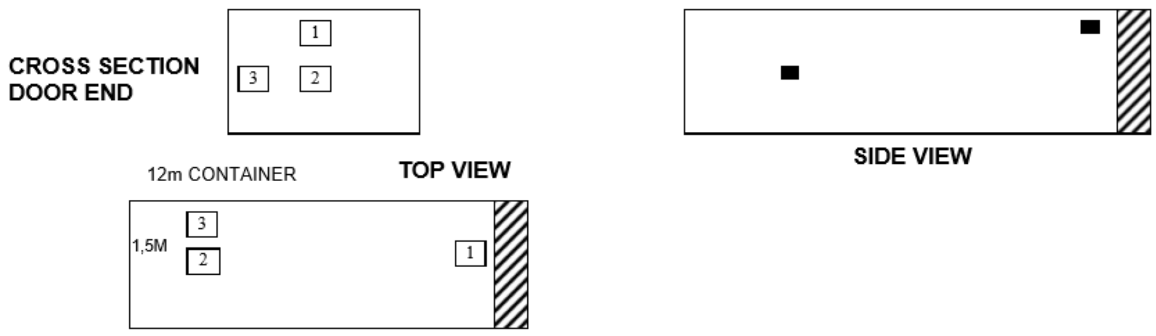


Figure 2.13: Sensor positioning in the container for Vietnam (same as China)

Source: Henning and Chetty (2020a:6)

Authorised PPECB technical personnel supervise the loading process and insert the on-board fruit sensors into the fruit as per special market protocol. The tip of the sensor must not extend beyond the fruit (Henning & Chetty, 2020a:5).

The temperature measured by the fruit on-board sensors may not exceed 0.8 °C for 20 days or 1 °C for 19 days, known as the on-board sterilisation process. After 20 days with a pulp temperature below 0.8 °C or after 19 days with a pulp temperature below 1 °C, the cold treatment protocol is completed and step-up temperature options may be considered by the exporter (PPECB, 2020:5).

2.8.6 Loading of refrigerated containers

The PPECB performs the cleanliness and pre-trip inspections as per international and ISO standards at the container depots (PPECB, 2020:3). No container may be loaded without prior PPECB approval (PPECB, 2020:3). Each container unit must be inspected before it is loaded and must be in full working order (Luchsinger, 2015:4).

All containers must be loaded according to the IMO/ILO/UNECE code of practice for packing cargo transport units, to ensure safe loading and securing of cargo (Crous, 2019, personal interview).

The total floor surface must be covered to avoid short-circuiting of cold air, pallets may not exceed the horizontal red loading line in the container and pallets may not extend over the T-Bar at the back of the container (Henning & Chetty, 2020a:1).

Figure 2.14 illustrates pallet bases hanging over the T-Bar of containers.

Figure 2.14: Pallets overlapping the T-bar at the back of the container

Photo credit, Researcher, 2020

A PPECB inspector must be present during the loading of all special market cold sterilisation containers. Figure 2.15 illustrates a PPECB inspector during the loading of a container.

Figure 2.15: PPECB present during loading of container

Photo credit, Researcher, 2020

2.9 Packaging

Packaging has two functions, namely marketing and logistics. The marketing function is used as a form of promotion and advertising. The logistical function is used firstly, to protect the product from damages and contamination. Secondly, packaging can improve storage, handling and transport, lowering logistical costs (Pienaar & Vogt, 2012:281).

The number of ventilation holes has a direct influence on the pre-cooling period and quality of the fruit (Hurndall, 2005:25). Ventilation holes in packaging material will impact the efficiency of the cooling process and hydration levels of the packed grapes (Luchsinger, 2015:1). Inferior postharvest grape quality can be ascribed to either deficient or excessive moisture in the cartons (du Plessis, 2003:6). The carton ventilation holes should be 100% symmetric to allow optimum airflow but the strength of the cartons should not be compromised by the ventilation holes (Luchsinger, 2015:1).

Figure 2.16 illustrates the alignment of carton ventilation on a packed pallet.

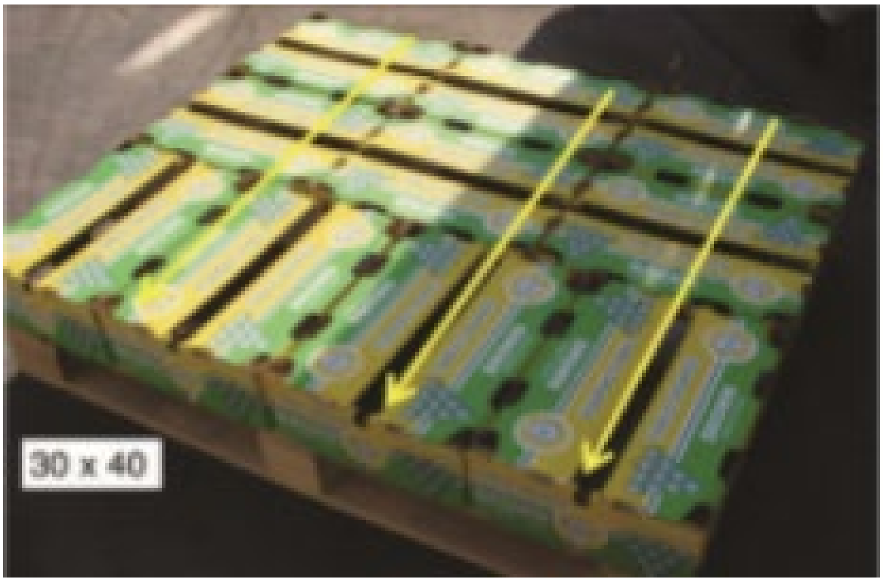


Figure 2.16: Alignment of carton ventilation on a packed pallet
Source: Luchsinger (2015:1)

The pallet size determines how many pallets will fit into a container. Package design influences the efficiency and effectiveness of the entire supply chain in terms of functions, features, information and cost aspects (Pienaar & Vogt, 2012:282).

Sulphur dioxide (SO_2) is used for fungal treatment and serves as an oxidant in table grapes (Luchsinger, 2015:2). SO_2 gas-generating sheets are inserted into each carton to limit the growth of *Botrytis cinerea* on the grapes during post-harvest storage (Hurndall, 2005:15).

2.10 Transport

Transport is the moving of goods from one area to another (Pienaar & Vogt, 2012:64). There are five modes of transport, namely, road transport (trucks), rail transport (trains), water transport (ships), air transport (aircraft) and pipelines (de Villiers et al., 2017:15).

In the South African table grape special market industry, a few modes of transport and processes take place. Firstly, the moving of harvested grapes from the orchard to the packhouse facility takes place via road transport. Secondly, after packaging the grapes, they are moved to a cold storage facility using road transport. Thirdly, if the cold storage facility is not a registered inspection facility for special and cold sterilisation markets, these pallets are moved to a registered cold store and inspection facility via road transport. Fourthly, pallets are loaded into a container and transported to the port using road transport. Lastly, pallets are shipped to the port of destination via water transport (PPECB, 2020:5).

2.10.1 Refrigerated trucks

Refrigerated trucks are most frequently used for road transport from pack house or cold storage facility to special market cold storage facilities, to always keep the cold chain in place during the transfer of pallets (Mans, 2019, personal interview). Refrigerated trucks operate by absorbing heat at one point and dispensing it at another, by circulating a refrigerant between two points. A compressor circulates the refrigerant through the system (Ashby, 1995:2).

There are two systems of circulating air in refrigerated vehicles. Figure 2.17 indicates the top-air delivery system and Figure 2.18 indicates the bottom-air delivery system (Ashby, 1995:4).

The top-air delivery system discharges air from the front ceiling. The air travels over the top of the load, down between the end of the load and rear doors and under and through the load to return to the refrigeration unit at the front of the vehicle (Ashby, 1995:5).

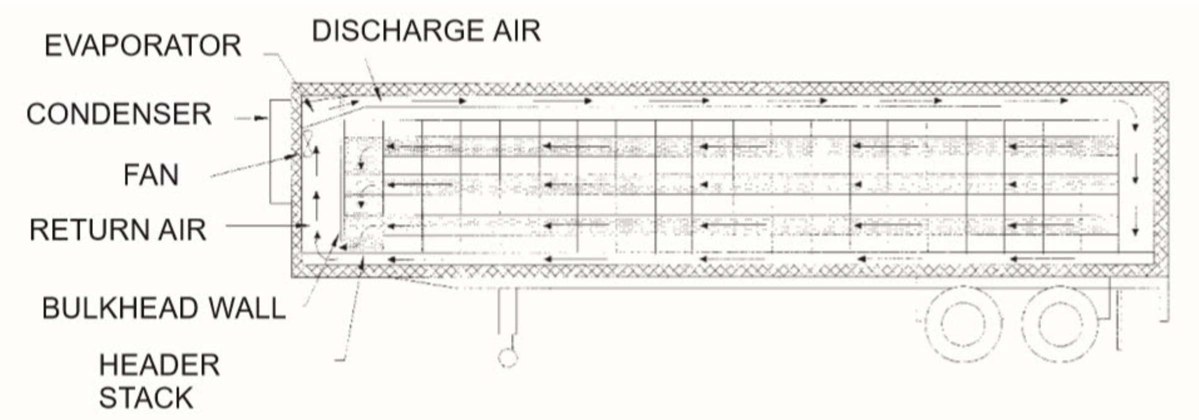


Figure 2.17: Top air delivery system
Source: Ashby (1995:5)

The bottom-air delivery system forces refrigerated air down the front bulkhead and under the load through a T-rail or T-Bar floor and then vertically up through the load (Ashby, 1995:6).

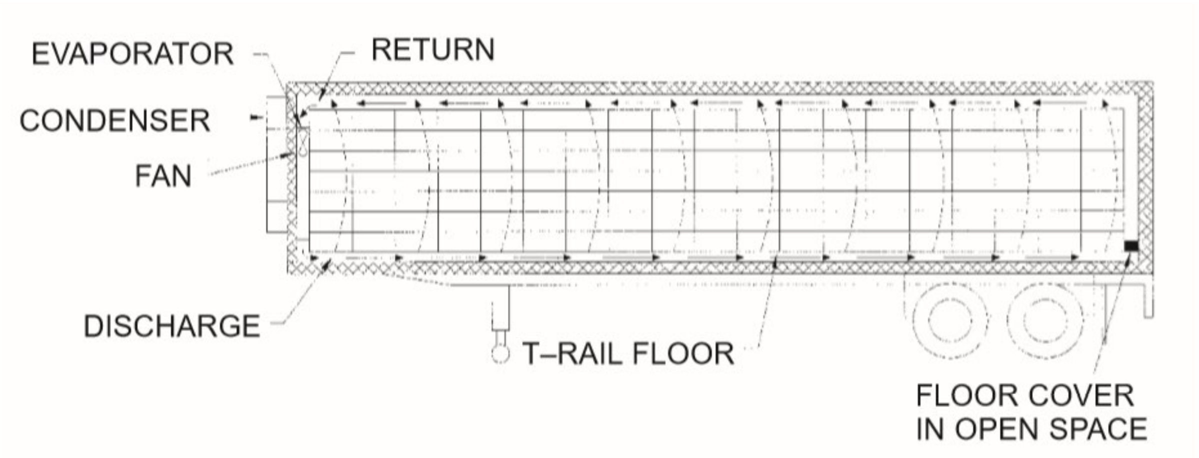


Figure 2.18: Bottom air delivery system
Source: Ashby (1995:5)
Loads must be stacked to enable proper air circulation in refrigerated trucks (Ezeike & Hung, 2009:531). Figure 2.19 indicates two loading methods for a refrigerated truck to have optimum air circulation.

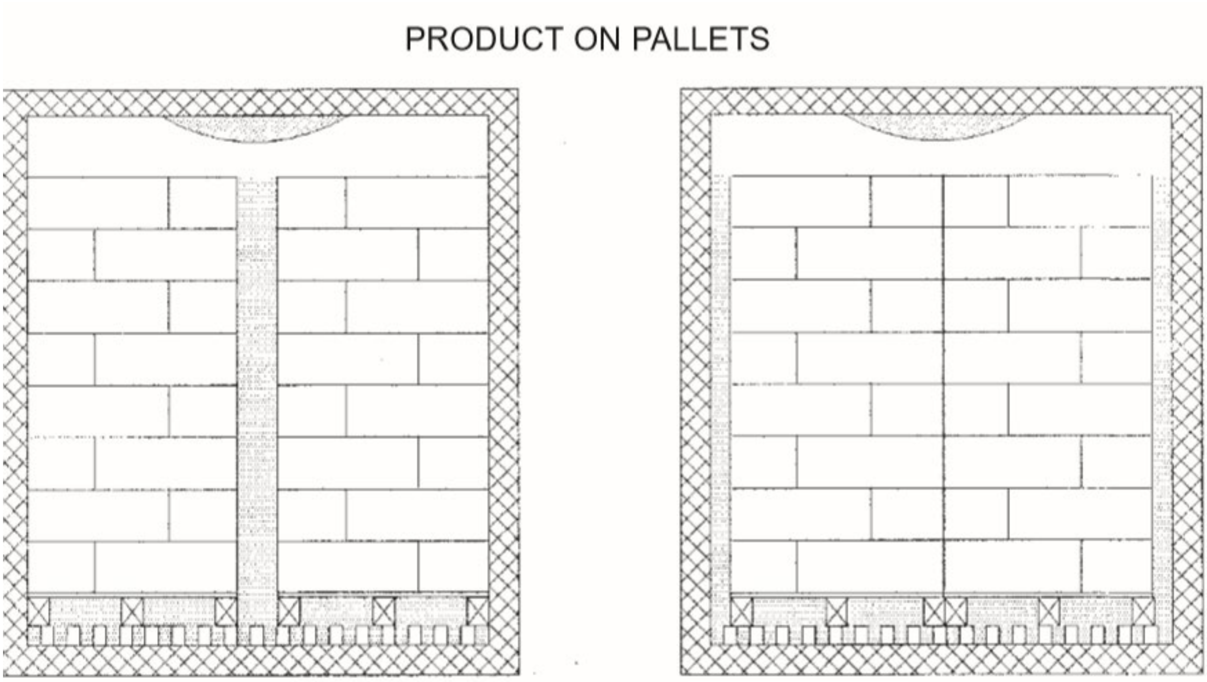


Figure 2.19: Wall loaded and centre loaded

Source: Ashby (1995:25)

2.10.2 Refrigerated containers

Refrigerated containers are also known as reefer containers and are a transport unit, not a mobile cold store (Henning & Chetty, 2020a:1). An external source of electricity of 360-380V is required to power the cooling unit and air circulating fans (Henning & Chetty, 2020a:1). Reefer containers are available in 6 and 12-metre units (Henning & Chetty, 2020a:1). Cold air is supplied into the container from the bottom of the container under the T-bar and illustrated by Figure 2.20 (Getahun, 2017:147).

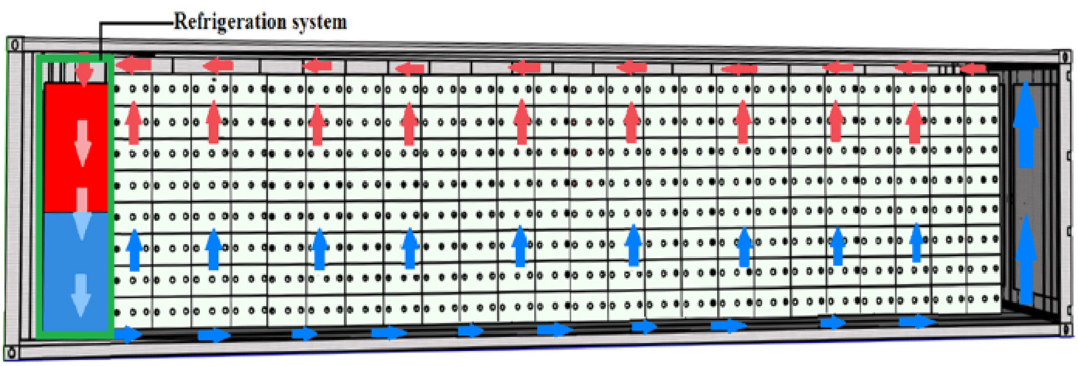


Figure 2.20: Airflow in a container (blue arrow = cold supply air; red arrow = warmer return air)

Source: Getahun (2017:147)

Figure 2.21 illustrates the container diagram and T-bar diameter of a 12m container.

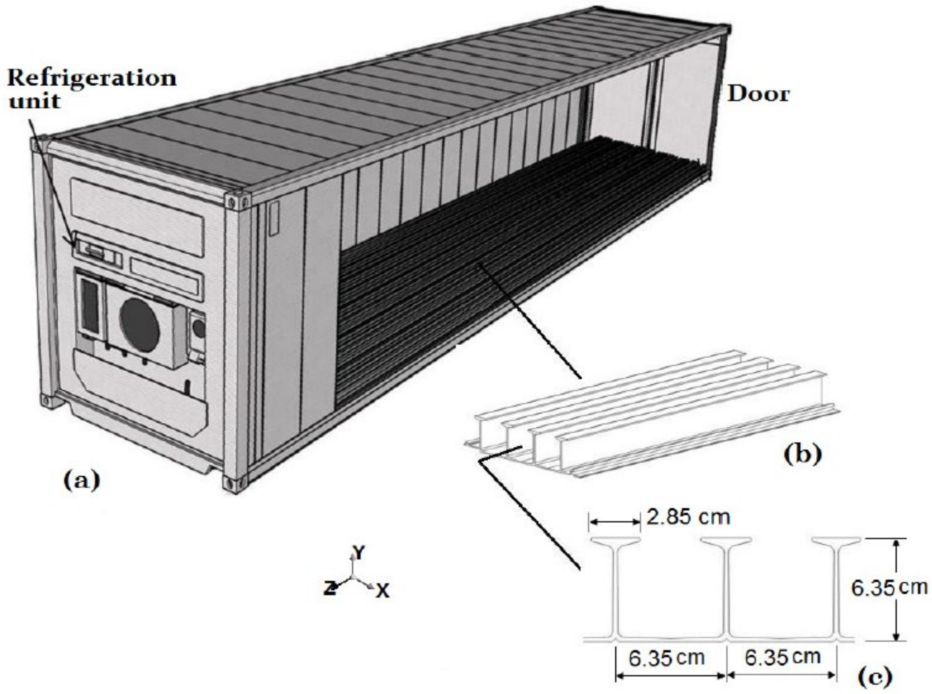


Figure 2.21: a) 12m container, b) T-bar, c) diameter of the T-bar
Source: Getahun (2017:54)

A T-bar is the grid running along the length of the reefer floor. It gets the name from the T-shaped cross-section of the aluminium extrusions that forms the floor (Getahun, 2017:10).

The floor was designed for optimal airflow in the container (Getahun, 2017:10).

Previous studies indicated that the average ambient temperature of the first pallet to be loaded into the container was more than 1 °C cooler than the pallet loaded at the door of the container (Goedhals-Gerber et al., 2017:368).

Previous studies done indicated that the majority of the temperature breaks in the cold chain occurred during the loading process (Haasbroek, 2013:156).

The South African table grape special and cold treatment export market protocols are designed for the loading of reefer containers and conventional shipping (PPECB, 2020:4). Reefer container loading is more commonly used than conventional shipping, especially in special cold sterilisation markets. Conventional shipping is no longer used for loading to special cold sterilisation markets in the SATI. It is only used for citrus exports to special cold sterilisation markets (PPECB, 2020:6).

The risk with reefer containers is that reefer units can fail, causing a rapid rise in temperature (Ruiz-Garcia, 2010:15). It is, therefore, important that the shipping line monitor the reefer containers regularly.

2.11 Special export markets

The National Plant Protection Organisation (NPPO) of South Africa has a bilateral agreement with various countries for different products to service export programmes according to specific protocols, known as special export markets (DAFF, 2010:12). Each special export market has its own specific protocol. DALRRD and the PPECB enforce these protocols. All food business operators (FBOs) must be registered with DALRRD and receive unique codes. The various code subsections are Packhouse Code (PHC), Production Unit Code (PUC), Commercial Cold Store Code (CCS), Container Depot Code (CD) and Transport Operator Code (TRANS). The PUC must be marked on all cartons packed with products of that specific production unit. It is necessary for traceability for food safety, quality, sanitary and phytosanitary reasons (DAFF, 2010:3).

All FBOs intending to export fruit to special markets must apply for phytosanitary approval and registration. DALRRD Directorate: Agriculture Products Inspection Services (D: APIS) will inspect the orchard, packhouse and inspection point before the FBO is approved for each special market. Special markets listed by DAFF for table grapes are China, the United States of America, Thailand, Israel, Japan and Europe (DALRRD, 2019b:2).

China and Vietnam's phytosanitary special markets are explained below as they form part of the research study, the other phytosanitary special markets are indicated in Appendix S: Cold Treatment and Phytosanitary Guide for Table Grapes.

The DALRRD inspectors only work from 09:00 to 15:00, Monday to Friday (Crous, 2019).

2.11.1 China

All table grape varieties may be exported to China, but before any export can take place registrations, inspections and cold treatment must take place (DOA, 2007:2).

All the following must be registered and approved annually before table grapes can be exported to China (DOA, 2007:2):

a) Production Units (PUC)
b) Pack houses (PHC)

c) Vineyard blocks

d) Cold treatmentinspection points

Inspections: all fruit packed for China are inspected for quality and marking requirements by the PPECB. DALRRD conducts a phytosanitary inspection for any quarantine pests not allowed into China (DOA, 2007:2).

Marking requirements for China:

本产品输往中华人民共和国

(DOA, 2007:3). Only new cartons may be used. No used or relabelled cartons are accepted (DOA, 2007:3).

An example of a Chinese box-end label that contains all the required information is illustrated in Figure 2.22.

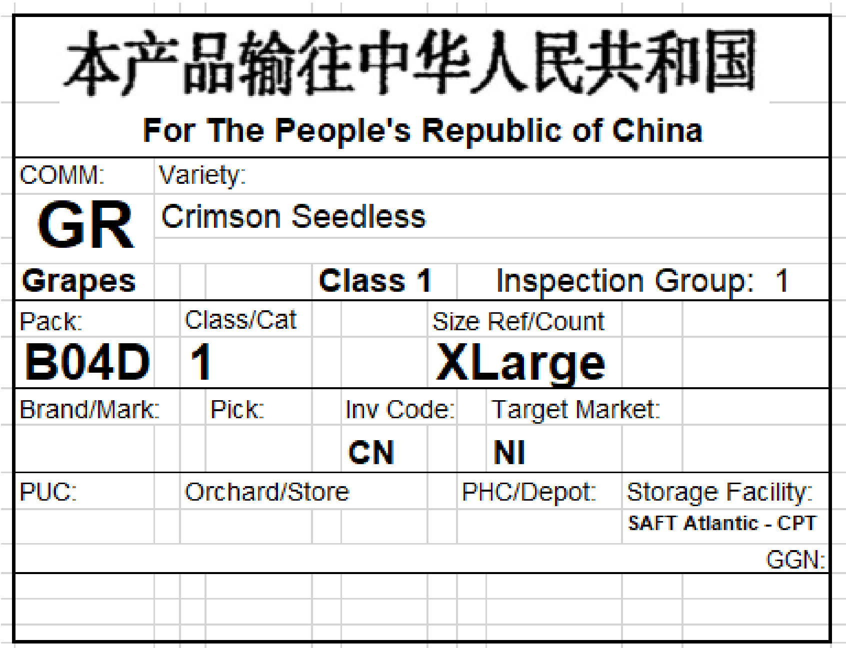


Figure 2.22: Example of a Chinese box-end label

Source: Adapted from Crous (2019)

Figure 2.23 illustrates all the special market cold sterilisation facilities registered by DALRRD and the Chinese government for the specific season the research was done.

CAPE FRUIT COOLERS- CFC-CPT
Cold Harvest-CPT
ETHEKWINI COLD STORES (Pty) Ltd- ECS-D
GOCHILL
GOGO COLDROOMS (Pty) Ltd- Gogo-L
PE COLD STORAGE- PECS Coega
SAFT Killarney-CPT
Rooipad Cold Rooms, Augrabies- RPD- AUG
Precool Cold Storage
New: CAPE FRUIT COOLERS RICHMOND- CFCRICH-CPT
New: SAFT Atlantic-CPT

Figure 2.23: Registered storage facilities for the 2019-2020 season

Source: DALRRD, FPEF, Hortgro, PPECB & SATI (2019:3)

The PPECB conducts a quality inspection on a 2% sample of the consignment. A PPECB intake document illustrates the consignment size. The PPECB inspector indicates what samples need to be drawn for inspection (Department of Agriculture, Forestry & Fisheries [DAFF], 1990:7).

The quality inspection by the PPECB is done strictly according to the CODEX standards:

a) Berries and bunches may not be affected by rot or deterioration;

b) Must be clean and free of any visible foreign matter;

c) Free of pests and damage caused by pests; free of any foreign smell and taste;

d) Berries must be whole, well-formed and normally developed.

The condition of grapes must be good enough to withstand transport and handling for each target market. The sugar to acid ratio must at least be equal to:

a) 20:1 if the Brix level is greater than or equal to 12.5 °Bx and less than 14 °Bx.

b) 18:1 if the Brix level is greater than or equal to 14 °Bx and less than 16 °Bx (Codex Alimentarius, 2007:1).

DALRRD inspection services conduct a phytosanitary inspection of each consignment packed for China. The accompanying document details the consignment. The minimum consignment size is 10 pallets. No mixed PUCs per pallet are allowed. A consignment may have a maximum of three PUCs per accompanying document but only one PHC (DOA, 2007:4). Figure 2.24illustrates an accompanying document.

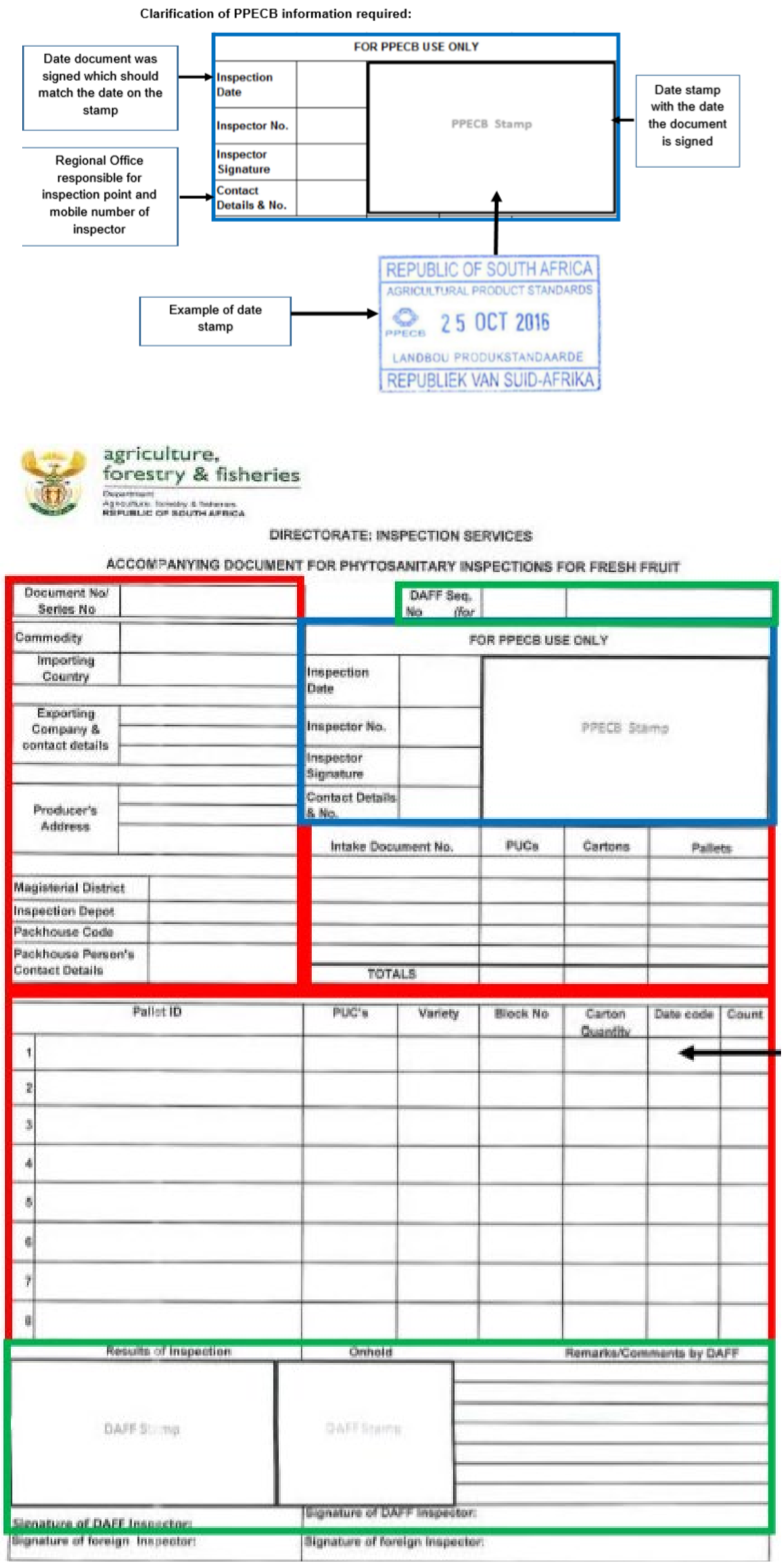


Figure 2.24: Accompanying document template

Source: PPECB (2016:1)

Only original accompanying documents are accepted by DALRRD before inspection takes place (DOA, 2007:4). No intake documents or accompanying documents may be signed at intake points, ports or phytosanitary inspection points. Documents need to be signed where the PPECB quality inspection takes place (DOA, 2007:4). Of the total cartons, 2% on the accompanying document are pulled for inspection from each pallet (DOA, 2007:4).

During the phytosanitary inspection, DALRRD will reject a consignment if any quarantine pests are found, marking requirements do not comply and if the documentation does not comply with the protocol (DOA, 2007:5).

According to DOA (2007:1), critical quarantine pests include:

- *Ceratitis capitata* – Mediterranean fruit fly
- *Ceratitis rosa* – Natal fruit fly
- *Thaumatotibia leucotreta* – False codling moth
- *Bactrocera dorsalis* – Invasive fruit fly
- *Frankliniella occidentalis* – Western flower thrips
- *Planoccus ficus* – Mealie bugs
- *Eutypa lata* – Grape canker
- *Aleurocanthus woglumi* – Citrus blackfly
- *Hemiberlesia rapax* – Greedy scale
- *Raglius apicalis* – Apical spot

Only containers may be loaded to China; no conventional shipments are allowed (DOA, 2007:10).

2.11.2 Vietnam

On 1 December 2019, the Vietnamese market became a special phytosanitary market (DALRRD, 2019a:2).

Registration of orchards, packhouses, production units and inspection cold treatment is mandatory for exporting to Vietnam (DALRRD, 2019a:1). Pre- and post-harvest pest management and inspections are critical for exporting to Vietnam (DALRRD, 2019a:1).

All packhouses planning to pack grapes for Vietnam need to be registered annually with DALRRD (DALRRD, 2019a:1). All production units producing grapes for Vietnam need to register the specific vineyards and the PUC with DALRRD annually (DALRRD, 2019a:1). Inspection cold sterilisation facilities need to register annually with the PPECB and DALRRD (DALRRD, 2019a:1).

Good agricultural practices are essential to managing pest control at pre- and post-harvest stages (DALRRD, 2019a:2). Vineyards must be monitored for pests and ensure that all vineyards are free from quarantine pests (DALRRD, 2019a:2)

The wording "For Vietnam" and the standard traceability requirements set by the minimum standard for the export of grapes must appear on each carton (Codex Alimentarius, 2007:4). The minimum requirements are the commodity, variety, class, pack type, target market, PHC, PUC, vineyard blocks, berry size and the wording "Produce of South Africa" (Codex Alimentarius, 2007:4). Only new unused cartons may be used. No labelling may be stuck over previous labelling (DALRRD, 2019a:2).

The following inspections are mandatory for all grapes exported to Vietnam.

a) PPECB quality inspections will be done on 2% of the grapes per consignment as per the minimum standard set by the industry (Julius, 2020:6).
b) DALRRD will conduct a phytosanitary inspection on 2% of the cartons per consignment (DALRRD, 2019a:3). An accompanying document will represent the consignment. The minimum consignment size is 10 pallets. No mixed PUCs per pallet are allowed. A consignment may have a maximum of three PUCs per accompanying document but only one PHC (DALRRD, 2019a:2).
c) Upon arrival in Vietnam, every consignment will be inspected by Vietnamese officials (DALRRD, 2019a:5).

2.12 South African ports

Ninety-five percent of all trade to the Southern African region passes through ports in South Africa (Haasbroek, 2013:28). South Africa has eight commercial ports, namely Richards Bay, Durban, East London, Ngqura, Port Elizabeth, Mossel Bay, Cape Town and Saldanha. Transnet Port Terminals (TPTs) handle all container, mineral bulk, agriculture bulk and roll-on/roll-off operations at these ports. TPT operates container terminals at the Durban, Ngqura, Port Elizabeth and Cape Town ports. Each of these container terminals utilises the Navis system, which provides integrated real-time shipping information to all relevant parties (Transnet, 2020:8).

Ports most frequently used for the export of table grapes to special cold sterilisation markets are Cape Town, Port Elizabeth and Ngqura (DALRRD, 2019b:5).

Delays and congestion in the ports are a point of concern for all port users. Delays and congestion can be caused by the following factors:

a) Lack of poorly maintained infrastructure or equipment capacity (Potgieter, Havenga & Goedhals-Gerber, 2020:4)
b) The majority of containers are transported via trucks, which leads to congestion at the port gate during peak seasons (Haasbroek, 2013:28)
c) Wind delays at the Port of Cape Town are a major concern (Brooke, 2020:19).
d) Breakdown of equipment and machinery can result in delays inside the port (Haasbroek, 2013:28). Landside equipment is in poor condition (Brooke, 2020:19).
e) Strike actions, tools downed and "go-slows" have affected the port operations heavily (Brooke, 2020:19).

2.13 NAVIS and Refcon systems

The NAVIS and Refcon systems are part of the reefer container management process (Goedhals-Gerber et al., 2017:369).

NAVIS is an IT web-based terminal operating system that allows planning, scheduling and tracking of cargo by TPT and their clients along land and terminal routes (Goedhals-Gerber et al., 2017:369).

The NAVIS pre-advice transaction entry is illustrated in Figure 2.25, showing the import information necessary to complete the pre-advice for each container.

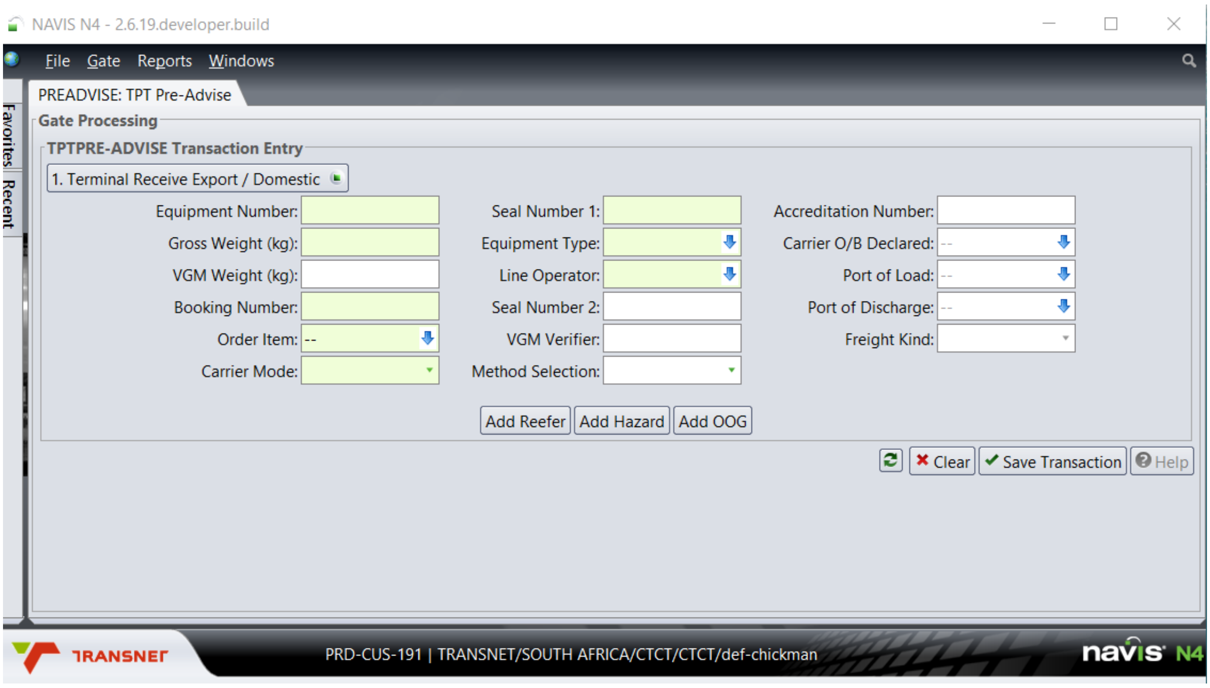


Figure 2.25: Navis pre-advice transaction entry window

Source: Navis (2020:5)

Refcon is an IT system that remotely monitors the state of reefer containers in the stackyard of the CTCT (Goedhals-Gerber et al., 2017:370). Port operators can view the functionality of all reefer containers on their computer screens.

2.14 Perishable Products Export Control Board

The PPECB is a designated assignee of the DALRRD that delivers the following services to South African perishable produce (PPECB, 2020:8).

a) Cold chain management: The cold chain management department ensures that all products leaving the country are handled, stored and transported at specific temperatures and optimum conditions.

b) Product Inspection Services: A quality inspection must take place on all perishable products destined for export. Only products that have passed inspections conducted by the PPECB may be exported. This ensures that all South African produce that is exported meets the same requirements for quality purposes.

c) Food Safety Services: The PPECB ensures that the FBOs comply with the standards relating to food safety and hygiene practices for agricultural produce.

d) Laboratory and Analytical Services. SAMSA Accredited Services: The mandatory amendments to the international convention for the Safety of Life at Sea (SOLAS)

Chapter V1, Part A, Regulation 2 were promulgated in the Marine Notice No. 5 of 2016 and brought into force on 1 July 2016. SOLAS regulations are based on two methods. Method 1 weighs the container before and after loading to determine the verified gross mass of the container. Method 2 weighs the content of the container and adds the tare weight of the container to determine the verified gross mass. Each weighing point is audited and receives a certificate of recognition.

The PPECB is a statutory body under the provisions of the Perishable Products Export Control Act No. 9 of 1983 of the Republic of South Africa. The PPECB is authorised to apply and ensure that accurate calibration of refrigeration equipment, correct stacking of pallets for air circulation control during forced-air cooling, correct handling and loading procedures are followed to ensure minimum temperature gain during shipment and voyage and to be temperature-specific according to protocols set by authorities of both the importing and exporting countries (Henning & Chetty, 2017a:1).

2.15 Department of Agriculture, Land Reform and Rural Development

DALRRD was previously known as the Department of Agriculture, Forestry and Fisheries (DAFF).

The vision of DALRRD is, “Equitable access to land, integrated rural development, sustainable agriculture and food security for all” (DALRRD, 2020:2).

According to DAFF (2020:3), the mission of DALRRD is:

To accelerate land reform, catalyse rural development and improve agricultural production to stimulate economic development and food security through; transformed land ownership, agrarian reform, implementation of an effective land administration system, sustainable livelihoods, innovative sustainable agriculture, promotion of access to opportunities for youth, women and other vulnerable groups and integrated rural development.

Outcome goals set by DAFF (2020:3) are:

…to improve governance and service excellence, spatial transformation and effective land administration, equitable access to land and producer support, increase production in the agricultural sector, increase market access and maintain existing markets, integrate the rural economy and enhance biosecurity.

2.16 Current international best practices for table grapes

International best practices can be defined as accepted methodologies or techniques that deliver superior results in comparison to other methods and have become the standardised method used across the world (Fedeli, 2019:71).

South African table grapes are highly sought after due to supplying consistent quality, supplying the demand of each market segment, managing the cost and building solid relationships (Post-Harvest Innovation Programme, 2017:146).

The whole supply chain has an impact on supplying consistent quality, and it is therefore, necessary to implement the best practices to achieve consistent quality.

The first stage of the chain is the production of table grapes. It is important for all producers planning to export table grapes to follow the current best practices. Safety and sustainability form the main principles in the current international best practices for the production of table grapes (AgriOrbit, 2020:4). To ensure the safety of employees and the safety of consumers eating the fruit, employers must provide and maintain a safe and healthy work environment (International Labour Organization, 2011:3).

Food safety refers to handling, preparing and storing food to reduce the risk of individuals becoming sick from foodborne illnesses (Australian Institute of Food Safety [AIFS], 2020:2). Cleaning and sanitising of all surfaces, personal hygiene, storing, cooling and heating of food and effective pest control practices through the chain form the basic principles of food safety (AIFS, 2020: 2). Traceability is critical to link any food safety problem directly to a specific country, packhouse, producer and vineyard (DAFF, 2010:7). Each agricultural farm planning to export must be registered at DALRRD as an FBO and will receive a unique production unit code (PUC) from DALRRD. The packing facility must also be registered and will receive a unique packhouse code (PHC) (DAFF, 2010:3). During the packing process, each carton of fruit must have a box-end label. Each target market has different requirements, but the minimum requirement set by DALRRD is that the following detail must appear on each carton for optimal traceability: The words "Produce of South Africa", class of the product, the name and address of the exporter or packhouse, PUC code, product type, the variety and the size of the product (DAFF, 2010:8).

Sustainable means "involving the use of natural products and energy in a way that does not harm the environment that can continue or be continued for a long time." (Oxford Learner's

Dictionaries, 2020). Climate, energy, soil and water are the natural components that form the basis of sustainability in the agricultural sector. Growers and producers can minimise the climate impact and energy use by performing preventative maintenance on equipment, replacing inefficient equipment, using the minimum amount of fertiliser needed, low-energy irrigation and optimizing the size and efficiency of farm vehicles (Sustainability Consortium, 2016:2). Planting cover crops between vineyard rows protects soil against erosion, reduces weed growth and replenishes soil nutrients (Union of Concerned Scientists, 2017:4). Optimum pest management is critical to reduce the residue levels on the fruit, prevent beneficial insects from dying and creating an ideal ecosystem (Metcalf & Luckhman, 1994:15). Sustainable supply chain governance systems (SSCG) are implemented in developing countries like South Africa to improve environmental and social conditions of production operations (Vermeulen, 2010:147). SSCG is also used as a tool to ensure constant supply and controlled quality of products, by using certification schemes or standards (Vermeulen, 2010:152).

Figure 2.26 illustrates the current SSCG systems used during export to the European markets.

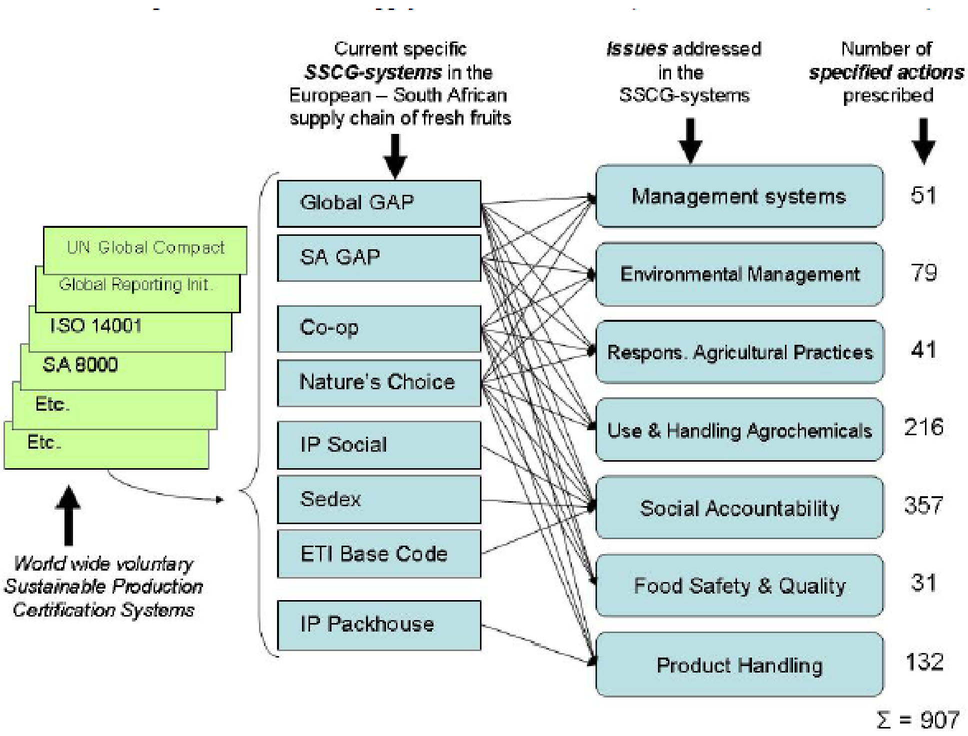


Figure 2.26: Current SSCG system used for export from South Africa to European markets

Source: Vermeulen (2010:153)

With all the current mandatory standards and voluntary standards used in the table grape industry, it is easy to see why South African table grapes are highly sought after.

Once all the standards and requirements are met, the fruit is packed. The cold chain then plays the critical role of keeping the product intact and in the best possible condition for consumers. Best practices used in the table grapes industry to maintain optimum cold chain integrity starts with harvesting grapes during cool temperatures below 30 °C, normally during the early morning hours (Haasbroek, 2013:126). To reduce the risk of condensation, keep grapes at a temperature above dew point until forced-air cooling can start, therefore, the temperature of pack houses should be kept between 18 °C and 25 °C with humidity levels between 85% and 95% (Haasbroek, 2013:126). Packed and palletised grapes must be placed under forced-air cooling within six hours after packing; strive to get the grape pulp temperature to 10 °C within 12 hours after packing (Valentyn, 2007:2). The optimum grape pulp temperature is -0.5 °C within 48 hours (Hurndall, 2005:5). Use strip curtains at cold store doors to prevent or limit warm air from entering the room (Haasbroek, 2013:126). Airlocked loading bays are ideal for maintaining the integrity of the cold chain (Haasbroek, 2013:127).

Gensets fitted on trucks is ideal for the cooling of the containers. During loading, the refrigeration system must be switched off and after loading, the Genset must be turned on for the refrigeration system to be switched on again (Henning & Chetty, 2017b:8). Temperature monitoring devices should be inserted into containers for monitoring air temperature. New technology also allows exporters to use these devices as tracking devices (Sensitech, 2020:2). All parties involved in the supply chain of table grapes should understand exactly what is required (Fedeli, 2019:37).

2.16.1 Summary of international best practices

If one looks at the keywords of the current international best practices, one will see sustainability, safety, standards and a certain set of cold chain rules. The main purpose of these practices is to ensure the sustainability of the soil, water, farms, table grapes, people and the export markets.

The branding used by SATI to launch a campaign in China fits ideally with the mission of the industry by following these best practices (see Figure 2.27).

Figure 2.27: Branding used in China by SATI

Source: (Phil, 2019:11)

2.17 Conclusion

The South African fruit industry is the 10th largest exporter of fruit in the world. It contributes 2.59% to the country's GDP and creates work opportunities for 400,000 people.

The table grape industry contributes R9 billion of the R74.1 billion that fruit contributes to the country's GDP, making the table grape industry a significant part of the South African fruit industry. The Hex River production area is the largest table grape production area in South Africa.

Considering the important function the table grape industry plays in the South African fruit industry, it is necessary to investigate the challenges faced in the industry and to deliver sound logistical practices throughout the supply chain. These logistical practices are to deliver finished goods (packed grapes), in correct quantities, on demand, at the desired location and in the preferred condition at the lowest cost.

Table grapes are non-climacteric fruit, they do not ripen after harvest and therefore table grapes have a shorter shelf life than climacteric fruits. Temperature control, packaging, force cooling, transport and loading patterns are all methods used to extend the shelf life of table grapes and deliver the fruit to the consumer in the preferred condition.

Knowledge of the supply chain, special markets and challenges at the ports all have an impact on the timeous delivery at the desired location.

Understanding the roles that PPECB and DALRRD play is mandatory for exporting fruit out of South Africa and it is important to work with the two role-players.

The literature review supplies the reader with the information to understand the importance of the table grape industry and why this research is necessary to determine a standard work method to achieve and maintain sound logistical practices for the cold treatment markets.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapter discusses the research design and methodology applied in the study. It explains the research approach to gathering the data necessary to conduct the research. It addresses planning, sampling, equipment, data collection and data analysis. A discussion on the ethical principles considered in the study concludes the chapter.

3.2 Reliability and validity of results

Reliability refers to consistency, using the same method to obtain the same result under the same circumstances (Middleton, 2019).

Reliability is split into three different types, namely Test/retest, Interrater and Internal consistency. Test/retest measures the consistency across time by repeating the research (Middleton, 2019). Interrater measures the consistency across different researchers and observers that conduct the study (Middleton, 2019). Internal consistency measures the consistency by determining if you get the same results from different parts of the study that are designed to measure the same thing (Middleton, 2019).

To ensure reliability in this research, Xsense BT9 temperature monitoring devices were used to measure the fruit pulp temperature across all three concepts investigated. Identical procedures were followed to insert the devices into the fruit pulp and cartons, ensuring the consistency necessary to deem the research reliable.

Validity refers to how accurately a method measures what it is intended to measure (Middleton, 2019). Validity can be evaluated by judgement or statistical methods, namely construct, content and criterion (Middleton, 2019). Construct is the existing theory and knowledge of the concept being researched. Content covers all the aspects of the concept being researched and criterion is the extent to which the result of a measure corresponds to other valid measures of the same concept (Middleton, 2019).

To ensure validity, Professor Nel from the Centre for Statistical Consultation at Stellenbosch University was consulted. Professor Nel conducted a power analysis to determine the total number of devices necessary to conduct the research over all three concepts. Professor Nel also assisted to determine the sample size for the survey used in the industry to determine the knowledge of the industry regarding the special cold treatment markets.

3.3 Definitions, concepts, constructs and variables

Temperature is an average measure of the kinetic energy of particles in an object (Cox, 2020:11). Increasing kinetic energy in an object causes a rise in temperature (Lucas, 2015:5). Thermometers are devices used to measure the kinetic energy in an object (Cox, 2020:11). There are three different temperature scales, namely, degree Celsius, Kelvin and Fahrenheit (Cox, 2020:12). For this study, degrees Celsius (°C) is used as the temperature scale.

Temperature forms the main construct and variable in the research, construct being the unit of measure and variables consist of ambient and pulp temperatures measured by the temperature monitoring devices. For this research, a temperature break in the cold chain was defined as any time in the data where the temperature reading measured 2 °C or warmer or -1.5 °C or colder for longer than 90 minutes. A temperature spike is defined as the temperature measuring 2 °C or warmer or -1.5 °C or colder for less than 90 minutes.

In this study, temperature data were recorded every hour.

Cold storage force cooling chambers and tunnels differ in size and layout, which may have an impact on the time it takes to cool fruit to the desired temperature. The variable does not have an impact on the research but it is necessary to mention that some cold storage facilities may reach -0.5 °C earlier or later than the current best practice of 48 hours.

The special market cold treatment chain comprises various stages. These stages are production (growth in orchards), harvesting, transportation, packing process, transportation, forced-air cooling (pre-cooling), phytosanitary inspection, cold treatment, loading, shipping and importing. The study researched the stages after the packing process until the importing stage, looking at the stages individually and creating an overall impression.

3.4 Design and methodology

This research makes use of a deductive research approach. Primary and secondary qualitative data were gathered and used with the quantitative data to form the mixed-method approach used for the research.

The rationale behind using a mixed method approach was to formulate the research findings in a more concise manner, by mixing the quantitative and qualitative data to form an emergent methodology of research.

3.4.1 Secondary qualitative data

Secondary data was the first form of data gathered through a review of current literature relevant to the research topics. The literature review gathered data from books, journal articles, industry procedures, presentations and websites on the Internet necessary to form the foundation of the research.

3.4.2 Primary qualitative data

Informal interviews were conducted with various role players in the industry to identify the logistical challenges faced regarding special cold treatment markets and discussed opinions of how to overcome these challenges.

Observations of the cold treatment chain were made at production units, packhouses, cold storage facilities, inspection facilities and sterilisation facilities. Observations were made by the researcher to identify the logistical challenges faced by the cold treatment chain and to gain a better understanding thereof.

A self-administered questionnaire was sent to persons working in the table grape industry and focussed on the special markets. Table 3.1 illustrates the demographic information of the survey participants.

Table 3.1: Demographic Information Table

Male	Female	Packhouse Managers	Cold Storage Facility Operations and Logistics Coordinators	**Exporters** Logistics Coordinators	**Exporters** Key Account Managers	**Freight Forwarders** Logistics Managers
15	16	3	4	11	6	7

The survey sought to determine the knowledge of the industry regarding exporting to special markets, if there was a need for special market cold treatment training and to identify some of the challenges faced regarding special cold treatment markets.

To determine the sample size, the researcher used a formula, with the assistance of Professor Nel from the Centre for Statistical Consultation at Stellenbosch University. The sample size was calculated and determined at 31.

$$\text{Sample size} = \frac{\dfrac{z^2 \times p\,(1-p)}{e^2}}{1 + \left(\dfrac{z^2 \times p\,(1-p)}{e^2 N}\right)}$$

p = the estimated probability.

If the estimated probability cannot be determined, use p = 0.5 (Nel, 2020, personal interview).

N = population size

There were 70 grape exporters listed at FPEF for the 2019-2020 season (Kruger, 2019:88-89).

Not all grape exporters export fruit to phytosanitary cold treatment markets and only 12 exported to the USA in the 2019-2020 season (Smit, 2020, personal interview). An estimated 45 exporters of the 70 listed export grapes to phytosanitary cold treatment markets, hence, the population size is 45.

e = Margin of error, percentage in decimal form.

The margin of error, also known as the confidence interval, can be described as the amount of random variation underlying a survey's results. With the population size of 45 and the types of questions asked in the survey, a 10% margin of error was selected (Nel, 2020, personal interview).

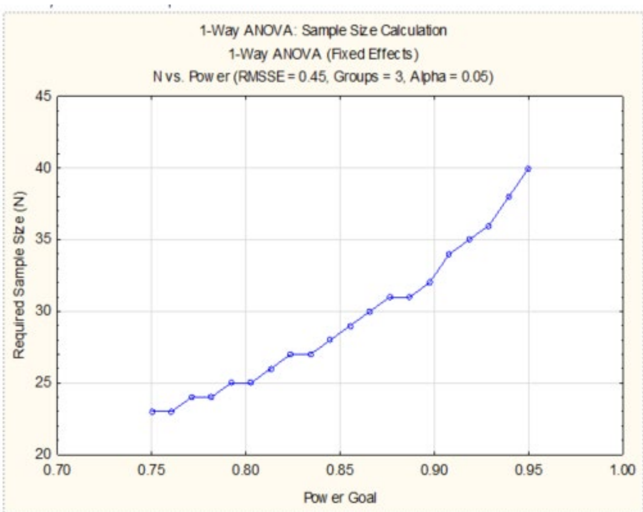
z = z-score

A confidence level of 95% was selected (Nel, 2020, personal interview), making the z-score 1.96 and Alpha 5%.

3.4.3 Quantitative data sources

The primary quantitative data used in the research was in the form of temperature trials that used Xsense HiTag BT9 radio frequency temperature monitoring devices to record the temperature data of the fruit pulp (BT9 Intelligent Supply Chain Solutions, 2020:1). The data were used to determine whether any temperature breaks and spikes occurred in the cold treatment chain. The monitoring devices were placed in the grapes, measuring the fruit pulp temperature in the centre of the pallet just after cartons had been packed and palletised at the packhouse. The devices completed the cold treatment chain and transit phase until the devices were removed at the distribution centres in China, Vietnam and Europe. The Xsense HiTag BT9 device is blue with an orange sticker on a string, making it easy for identification. The pallets were also clearly marked.

Nel (2019:4) from the Centre for Statistical Consultation at Stellenbosch University conducted a 1-Way ANOVA sample calculation to determine a suitable sample size, known as a power analysis. The main purpose of the power analysis is to determine the smallest sample size to detect the effect of a test at the desired level of significance (StatisticsSolutions, 2020:1). Figure 3.1 indicates the 1-way ANOVA sample calculation Nel (2019:4) used for each concept being researched.



	Sample Size Calculation Value
Number of Groups	3.0000
RMSSE	0.4500
Noncentrality Parameter (Delta)	4.0500
Type I Error Rate (Alpha)	0.0500
Power Goal	0.9000
Actual Power for Required N	0.9069
Required Sample Size (N)	33.0000

Figure 3.1: 1-Way ANOVA sample size calculation

Source: Nel (2019:4)

The sample size determined for each concept was 33. The root mean square standardised effect (RMSSE) is 0.45 and regarded as small. A RMSSE size of 0.25 is regarded as small, 0.75 as medium and 1.25 as large (Nel, 2019:4). It is ideal to achieve a small effect size between 0.25 and 0.75 (Nel, 2019:4).

The sample is represented by 33 temperature monitoring devices per concept, totalling 99 devices, as three concepts were researched.

Concept A: Also known as the breaching experiment

A breaching experiment method was used to purposefully violate the norm. The researcher breached the norm by sending warm, packed, palletised grapes directly from the packhouse to the cold treatment facilities in Cape Town, a distance of approximately 140 km. These pallets were transported in a refrigerated truck. The setpoint of the truck's cooling unit was set at 18 °C to maintain the same temperature from the packhouse to the cold storage facility where forced-air cooling cooled the fruit to the desired temperature as per each protocol. The temperature was maintained at 18 °C until forced-air cooling started, to reduce the risk of condensation.

Concept B: The standard method used over the years

Warm palletised grapes were loaded from packhouses to a commercial cold storage facility in the production area. Pallets were force cooled to under 1.5 °C and then transported to a cold treatment facility in Cape Town. Three trials were conducted, two in the Hex River production area and one in the Berg River area. This method is the standard method used over the years.

Concept C: Conducted in production area

This method was applied to determine the outcome of a cold treatment facility if in the same production area. Palletised grapes were loaded directly from the packhouse to a cold treatment facility in the same production area. Two trials were conducted.

Unfortunately, only 98 devices were obtained for the research study.

A total of 98 Xsense HiTag BT9 temperature monitoring devices (BT9 Intelligent Supply Chain Solutions, 2020:1) were divided between eight trials and three concepts.

Concept A used 34 devices. Three trials were conducted. Trial number 1 used 10 devices, trial number 2 used 12 devices and trial number 3 used 12 devices.

Concept B used 40 devices. Four trials were conducted. Trial numbers 1 and 4 took place in the Hex River production area and used 12 devices each. Trial numbers 2 and 3 took place in the Berg River production area and used 16 devices.

Concept C used 24 devices. Two trials were conducted, each using 12 devices.

In addition, Sensitech Temptale GEO devices were used as a comparison between the air and fruit pulp temperature in the transit section of the cold treatment chain. A total of 22 fruit pulp sensors were used in the cold treatment forced-air cooling tunnels to supply more temperature data of the land-base forced-air pre-cooling process or better known in the industry as Steri.

3.5 Ethical considerations

All participants that took part in the research study completed an informed consent document and gave permission for the researcher to use information supplied by them in the study. The consent document was explained and all participants were informed of their right to withdraw from the study at any time.

To maintain the anonymity of producers, cold storage facilities, cold sterilisation facilities, packhouses and exporters are referred to throughout the research as Packhouse A, B, C; Cold Storage Facility A, B, C; Cold Treatment Facility A, B, C and Exporter A, B.

3.6 Conclusion

A mixed method approach, using qualitative and quantitative data, was employed to obtain the necessary data to answer the research questions.

A survey was used to determine the knowledge of the industry regarding the special cold treatment markets and if training was required. Assisted by Professor Nel from the Centre of Statistical Consultation at Stellenbosch University, the researcher determined that 31 industry role players were necessary to complete the survey.

Temperature data gathered, using 98 devices, formed the quantitative data used in the data analysis. The breaching experiment challenging the norm is an effective method to deliver sound logistical practices and shorten the lead time.

CHAPTER 4: DATA ANALYSIS

4.1 Introduction

This chapter analyses the quantitative data collected for the research study.

The data were gathered from a survey and temperature trials using temperature monitoring devices. Figures in the form of graphs, charts and photographs provide visual presentations of the results, while raw data are presented in tabular format.

The data were gathered in the 2019/2020 grape season.

4.2 Equipment used for temperature data trials

4.2.1 Xsense HiTag BT9

The Xsense HiTag BT9 temperature sensor with fruit pulp spear measures and records fruit pulp temperatures and relative humidity of the fruit (BT9 Intelligent Supply Chain Solutions, 2020:5). The sensors work with radio frequency, transmitting data wirelessly to a control unit and from the control unit to an advanced cloud portal (Hale, Lopresti, & Stefanelli, 2019:1). The devices recorded the temperature reading every 60 minutes. Figure 4.1 is an image of an Xsense HiTag BT9 pulp spear.

Figure 4.1: Xsense HiTag BT9 with fruit pulp spear
Source: Healthcare Packaging (2013:5)

An overview of the Xsense system is shown in Figure 4.2 to create a better understanding of the system for the reader.

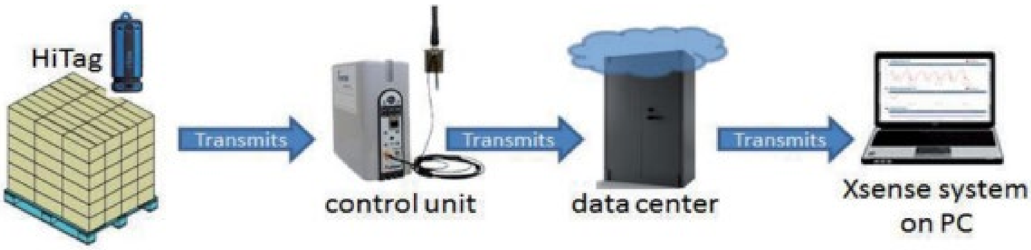


Figure 4.2: Overview of the Xsense system

Source: Hale et al. (2019:11)

4.2.2 Fruit pulp sensor in cold treatment tunnels

All cold treatment facilities must be equipped with an electronic recording system for recording air and fruit pulp temperatures on a continuous basis (Henning, 2019b:4). A minimum of two pulp sensors must be placed on the inside of the tunnel and one on the outside of the tunnel (Henning, 2019b:6). An example of an electronic recording system that is PPECB approved is shown in Figure 4.3. An image of the pulp sensors used inside and outside of tunnels is indicated in Figure 4.4.

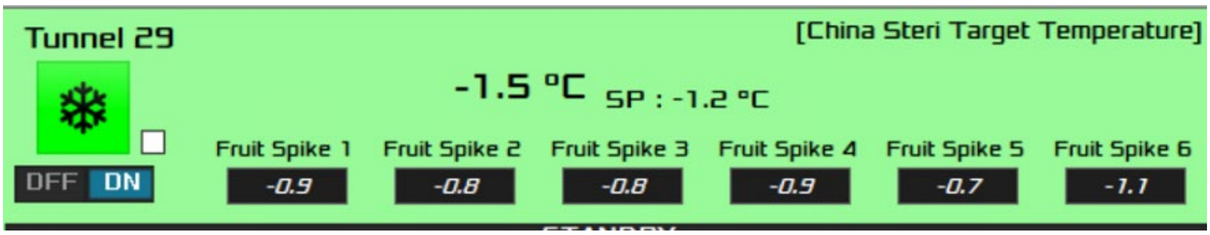


Figure 4.3: SCADA electronic recording system indicating fruit probe readings, air temperature and air setpoint

Photo credit, Researcher, 2020

Figure 4.4: Pulp sensor

Photo credit, Researcher, 2020

4.2.3 Sensitech TempTale GEO

Sensitech TempTale GEO sensors measure location and air temperature (Sensitech, 2020:11). The sensor sends data using 2G or 3G networks to a web-based tracking software program called SensiWatch. Figure 4.5 depicts the SensiWatch tracking program.

Figure 4.5: Location tracking with SensiWatch software

Source: Sensitech (2020:11)

An image of a Sensitech TempTale GEO Eagle is shown in Figure 4.6.

Figure 4.6: Sensitech TempTale GEO Eagle
Photo credit, Researcher, 2020

4.3 Software

4.3.1 SensiWatch

SensiWatch is a software service that effectively manages logistics and carrier performance across supply chains by tracking location and temperature (Sensitech, 2020:11). SensiWatch was used to obtain the air temperature from the back of the container during the voyage from Cape Town to the final destination, measured by the Sensitech Temptale GEO Eagles.

4.3.2 SCADA

Supervisory Control and Data Acquisition (SCADA) is a control system used for supervisory management by controlling industrial processes, monitoring, gathering data, directly interacting with sensors, valves, pumps and motors (Inductive Automation, 2020:1). Temperature monitoring data of fruit sensors in cold sterilisation forced-air cooling tunnels were gathered using the SCADA software.

4.3.3 Xsense information system

The Xsense information system enables web-based viewing of data with Internet access and information-based reports (BT9 Intelligent Supply Chain Solutions, 2018:11).

4.3.4 Microsoft Excel

Microsoft Excel is a program used for data entry, data management, accounting, financial analysis, charting, graphing and almost anything that needs to be organised (Corporate Finance Institute, 2020:8).

4.4 Data analysis approach

Qualitative and quantitative data were used in the study, namely a survey and temperature trial measurements.

4.4.1 Survey

The survey was used to identify the basic knowledge of the industry regarding the special market protocols in general and to determine whether there is a need for training the industry in special market protocols.

Thirteen questions were asked to 31 individuals. All 31 individuals that took part in the survey are role players in the special market table grape industry. The questions and answers of the 13 questions are listed in Table 4.1. Only questions 3, 4, 5, 6, 7, 8 and 12 had correct and incorrect answers. The correct answers are highlighted in yellow. Close-ended questions were asked by using multiple-choice questions and allowing the participant to choose between A, B and C.

Most of the participants answered the questions correctly, indicating that they know the protocols.

All the participants indicated that there is a need for additional training and information sessions regarding the cold treatment special markets.

Table 4.1: Survey questioniare summary of the 31 participants

Survey				
Questions	**Options**	**Answers of the 31 participants**		
		A	**B**	**C**
1. What is the easiest registration method?	A. Electronically with Phytclean B. Completing application form and courier it to DAFF in Pretoria C. None of the above	28	3	
2. Where do you find each special market protocol?	A. www.daff.gov.za (DAFF website) B. SATI C. Other	23	1	7
3. Can you re-use cartons for special markets?	A. Yes B. No C. Only for non-phytosanitary inspection markets	3	24	4
4. Can box-end labels be stickered above one another?	A. Yes B. No C. Only for non-phytosanitary inspection markets	2	29	
5. When must a storage facility name appear on the box-end label of a carton?	A. For all phytosanitary inspection markets B. Cartons packed for China C. None	11	20	
6. Which cold sterilisation markets need a phytosanitary inspection before cold sterilisation can begin?	A. Japan, Thailand, USA, Israel and China B. All cold sterilisation markets need a phytosanitary inspection. C. None	19	12	
7. For which markets must the inspection point apply for inspection?	A. China, USA, Israel, Japan and Thailand B. All special markets C. None	16	15	
8. What documents are needed for a phytosanitary inspection to take place?	A. Copy of Accompanying documents B. Original accompanying documents and PPECB signed consignment documents C. No documents needed	1	30	
9. Do you know what the PPECB yellow chart is?	A. Yes B. No C. Maybe	21	8	2
10. Do you know the different cold sterilisation protocols?	A. Yes B. No C. Maybe	22	5	4
11. Do you think that the cold sterilisation process has an effect on the quality of grapes?	A. Yes B. No C. Maybe	28	2	1
12. Why do certain markets request cold sterilisation?	A. To make sure the fruit is cold enough B. To kill phytosanitary insects, for example FCM C. Not sure	2	29	
13. Do you think there is a need for more training and information sessions on the cold sterilisation protocols?	A. Yes B. No C. Maybe	28		3

4.4.2 Temperature trials

The Xsense HiTag BT9 temperature devices were inserted into the centre of a pallet, one device per carton. This created a temperature data profile representative of the whole pallet, taking into consideration the airflow through the pallet. Figure 4.7 shows the temperature device positioning in cartons viewed from the top, the x indicates the device position.

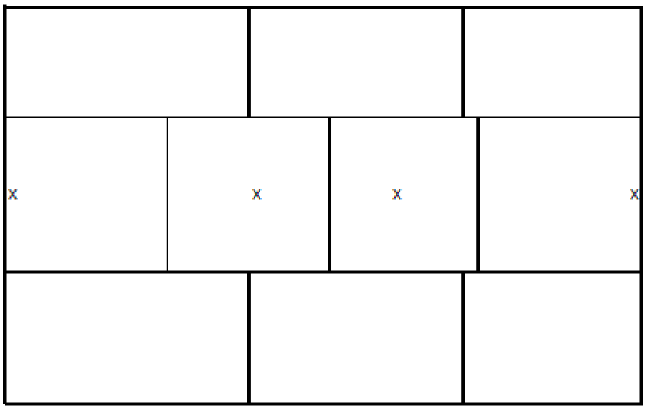


Figure 4.7: Diagram of where the sensors were placed, X indicating the sensor position

Figure 4.8 shows the sensors in cartons in the centre of the palletised pallet, indicated by the green and small orange stickers.

Figure 4.8: Sensors in cartons in centre of the palletised pallet, indicated by the green and small orange stickers

Photo credit, Researcher, 2020

Grapes were placed onto the sensor, covering it for optimal pulp temperature readings (see Figure 4.9).

Figure 4.9: Sensors placed into position
Photo credit, Researcher, 2020

Xsense HiTag BT9s are disposable and send data with radio frequency. This made it possible for the researcher to leave the sensors in the pallets and there was no need to physically collect them.

A summary of the Xsense HiTag BT9s used in the trials is contained in Table 4.2.

Table 4.2: Xsense HiTag BT9 summary

Concept Number	Packed date	Region	No. of BT9s	BT9 number	Pallet ID's	Container number
A	19/12/2019	Hex River	10	5222595, 5222590, 5222667	660091600105946647	SZLU9551666
				5345308, 5222586, 5345344, 5222677	660091600105946685	
				5222627, 5222631, 5222616	660091600105946630	
A	15/01/2020	Hex River	12	5244942, 5345082, 5244994, 5244915	460091600151957099	TEMU9625437
				5345081, 5345004, 5345091, 5345019	460091600151957082	
				5345339, 5244941, 5244981, 5244916	460091600151957129	
A	15/01/2020	Hex River	12	5345362, 5345072, 5345358, 5345074	460091601516358766	SZLU9355827
				5245002, 5345383, 5345335, 5345379	460091601516358742	
				5345376, 5345009, 5345310, 5244971	460091601516358759	
C	16/01/2020	Berg River	12	5244961, 5244934, 5244990, 5244917	060091600235664082	SUDU8074420
				5245000, 5244968, 5244926, 5244947	060091600235664099	
				5245006, 5244996, 5244958, 5345030	060091600235664167	
B	30/01/2020	Hex River	12	5244998, 5244957, 5244985, 5345340	560091600197953076	TCLU1244191
				5244913, 5345380, 5345092, 5345035	560091600197953069	
				5345077, 5244970, 5345309, 5245008	560091600197953057	
C	31/01/2020	Berg River	12	5244964, 5244911, 5245001, 5244954	160091600097379190	DFOU6157819
				5244937, 5244921, 5244929, 5345084	160091600097379206	
				5345069, 5345083, 5345378, 5345089	160091600097379213	

Table 4.2 continued

Concept Number	Packed date	Region	No. of BT9s	BT9 number	Pallet ID's	Container number
B	03/02/2020	Berg River	16	5345000, 5244943, 5244956, 5345088	360095142001912104	CXRU1070878
				5345299, 5345090, 5244924, 5244922	360095142001912036	
				5345042, 5244980, 5345049, 5244972	360095142001912210	TEMU9361503
				5244920, 5244952, 5345067, 5244939	360095142001912227	
B	21/02/2020	Hex River	12	5244986, 5345031, 5244936, 5244988	360091600186289786	SZLU9542793
				5244983, 5244982, 5345093, 5244960	360091600186289762	
				5345013, 5244944, 5245003, 5245004	360091600186289779	
		Total	98			

Three concepts were researched.

Concept A: Also known as the breaching experiment

The data of the breaching experiment was used to determine temperature breaks and spikes and also to shorten the cold treatment lead time from the packhouse to being loaded into containers. Palletised grapes were loaded directly from a packhouse in the Hex River production area and transported to a cold treatment facility in Cape Town. Three trials were conducted to gather data regarding this concept.

Concept B: The standard method used over the years

Palletised grapes were loaded from packhouses to a commercial cold storage facility in the Hex River production area. Pallets were force cooled to under 1.5 °C and then transported to a cold treatment facility in Cape Town. A trial was also conducted in the Berg River production area following the same protocol. Due to Covid-19, opportunities to gather information on special cold treatment markets were limited. The trial in the Berg River production area was conducted in the same way as the Hex River production area, by sending fruit from the packhouse to the cold storage facility in the area and from there to a cold treatment facility in Cape Town.

Three trials were conducted, two in the Hex River production area and one in the Berg River area.

Concept C: Conducted in the Berg River production area

This was to determine the outcome of a cold treatment facility in the same production area.

Palletised grapes were loaded directly from the packhouse to a cold treatment facility in the same production area. Two trials were conducted.

Trials were done on fruit destined for China and Vietnam's special cold treatment markets. Nine containers represented the nine different trials. Six of the nine containers went to China, one went to Vietnam with cold treatment, one went to Vietnam without cold treatment and one container went to Europe. The PPECB protocol for both the Chinese and Vietnamese markets states that fruit must be in forced-air cooling tunnels, with a minimum of two fruit pulp sensors in the inside of the tunnel and one fruit pulp sensor on the outside of the tunnel. Grapes are placed onto the sensors and the sensors are placed inside the carton. Before loading can take place, the cold treatment facility must supply the PPECB inspector with a 24-hour temperature printout for China and 12 hours for Vietnam. The researcher retrieved cold treatment printouts supplied to the PPECB for three of the six containers for China. The data of the fruit sensors were used to determine whether it was possible to accelerate the cold treatment process.

Sensitech TempTale GEO Eagles were used to measure the air temperature during the transit period of two containers. The data were supplementary to the fruit pulp temperature data readings. The devices were placed in the last pallet at the door of the container, known as the hot spot of the container. The data were also used to determine whether the air temperature differed from the pulp temperature.

The 1-way ANOVA sample size calculation completed by Nel (2019:4) indicated that all three concepts needed 33 samples to achieve an RMSSE of 0.45. Unfortunately, due to the COVID-19 pandemic, exports to China ended earlier than the researcher anticipated. The coronavirus in China occurred in the middle of the South African table grape season and led to uncertainty during January and February, causing trading to cease (Ferreira, 2020:1). Although there was a deviation of the sample size for each concept being researched, all RMSSE were still seen as small and ideal for the research.

The research in Concept A used 34 devices. The RMSSE of the sample was 0.44, which is seen as a small effect and ideal for the research.

Figure 4.10 illustrates the 1-Way ANOVA sample calculation for Concept A.

	Sample Size Calculation
	Value
Number of Groups	3.0000
RMSSE	0.4400
Noncentrality Parameter (Delta)	3.8720
Type I Error Rate (Alpha)	0.0500
Power Goal	0.9000
Actual Power for Required N	0.9027
Required Sample Size (N)	34.0000

Figure 4.10: Concept A; 1-Way ANOVA

Source: Nel (2019:4)

The research in Concept B used 40 devices. The RMSSE of the sample was 0.40, which is seen as a small effect and ideal for the research.

Figure 4.11 illustrates the 1-Way ANOVA sample calculation for Concept B.

	Sample Size Calculation
	Value
Number of Groups	3.0000
RMSSE	0.4050
Noncentrality Parameter (Delta)	3.2805
Type I Error Rate (Alpha)	0.0500
Power Goal	0.9000
Actual Power for Required N	0.9032
Required Sample Size (N)	40.0000

Figure 4.11: Concept B; 1-Way ANOVA

Source: Nel (2019:4)

The research in Concept C used 24 devices. The RMSSE of the sample was 0.53, which is seen as a small effect and ideal for the research.

Figure 4.12 illustrates the 1-Way ANOVA sample calculation for Concept C.

	Sample Size Calculation
	Value
Number of Groups	3.0000
RMSSE	0.5300
Noncentrality Parameter (Delta)	5.6180
Type I Error Rate (Alpha)	0.0500
Power Goal	0.9000
Actual Power for Required N	0.9059
Required Sample Size (N)	24.0000

Figure 4.12: Concept C; 1-Way ANOVA

Source: Nel (2019:4)

All data from the Xsense HiTag BT9 devices were downloaded from the Xsense information system to Microsoft Excel. Data were captured into spreadsheets in Excel. Line and bar graphs were plotted in Excel to supply a holistic temperature profile of each stage per concept.

For this research, a temperature break in the cold chain was defined as any time in the data where the temperature reading was 2 °C or warmer or -1.5 °C or colder, for 90 minutes or longer. A temperature spike is similar to the definition of a temperature break, but for less than 90 minutes.

4.5 Cold chain stages

4.5.1 Packing stage

This is the stage when the fruit is packed. In addition, this is the stage when the devices were inserted into the fruit and cartons.

4.5.2 Transfer stage

Pallets are consolidated and transferred to cold storage facilities using road transport.

4.5.3 Forced-air cooling stage

As explained in Chapter 2, this is the stage when cool air is forced through the pallets to remove the warm air from the fruit and cartons. By removing the warm air, the fruit is cooled down to the required temperature more quickly.

4.5.4 Storage and inspection stage

If grapes are at the correct temperature after the forced-air cooling stage, they are placed in holding rooms before being loaded. Pallets are also placed in a holding room if grapes are received at the correct temperature from the cold storage facilities and are waiting on the phytosanitary inspection to be conducted before the Steri stage can start.

4.5.5 Steri stage

This stage is also known as the inland pre-cooling cold treatment stage, where the fruit is cooled down to the average temperature of -0.5 °C with the forced-air cooling method. Different markets have different Steri protocols as explained in Chapter 2.

4.5.6 Loading stage

Loading of pallets out of the Steri tunnels into the container takes place as per each market protocol, as explained in Chapter 2.

4.5.7 Stack and shipping stage

After containers have been loaded at the cold treatment facilities, they enter the stack at the port for monitoring of temperatures and waiting for loading of the vessel to commence.

4.6 Concept A

Concept A is also known as the breaching experiment. To conduct the research, which was divided into three trials, 34 devices were used.

4.6.1 Concept A, Trial 1

Trial 1 was conducted on pallets destined for China. Ten devices were divided into three pallets. Pallet ID 660091600105946647 had three devices, namely 5222595, 5222590 and 5222667. Pallet ID 660091600105946685 had four devices, namely 5345308, 5222586, 5345344 and 5222677. Pallet ID 660091600105946630 had three devices, namely 5222627, 5222631 and 5222616.

Devices were inserted at 08:00 on 19 December 2019 at Packhouse A. The consignment containing pallet IDs 660091600105946647, 660091600105946685 and 660091600105946630 arrived at Cold Treatment Facility A at 17:13 on 19 December 2019. Pallets were loaded into the container on 22 December 2019 at 09:30.

Figure 4.13 illustrates the average temperature data of Trial 1 of Concept A.

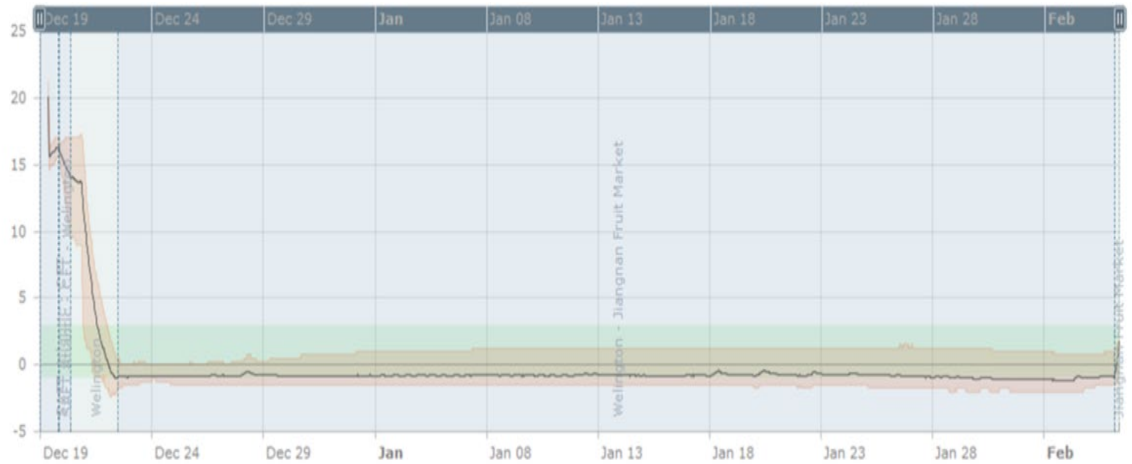


Figure 4.13: Average temperature, Trial 1, Concept A

Figure 4.14 illustrates the temperature data of the 10 devices used in Trial 1 of Concept A.

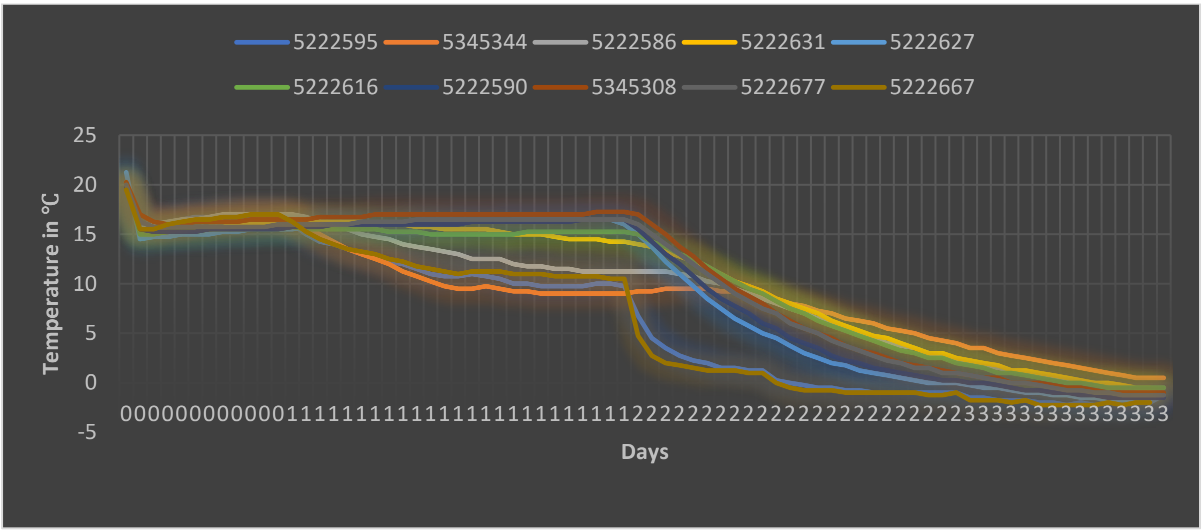


Figure 4.14: Temperature of the 10 devices used

4.6.1.1 Concept A, Trial 1: Packing stage

Starlight grapes were packed on 19 December 2019 at Packhouse A. Starlight is a large berry, red seedless variety (Unichoice, 2020:2.). Starlight ripens early in the season and is a mutation of Prime Seedless (Unichoice, 2020:2). The grapes were packed in B04I cartons, known as 4.5 kg cartons, of which 180 cartons were palletised per pallet base.

The researcher inserted the devices at 08:00 while the pallets were palletised, whereafter the pallets were moved to a holding area that was set at 18 °C. Pallets were kept in the holding area until 14:13.

Figure 4.14 illustrates the temperature data of all 10 devices during the packing stage. The stage from packing until the pallets were moved to the next stage took six hours.

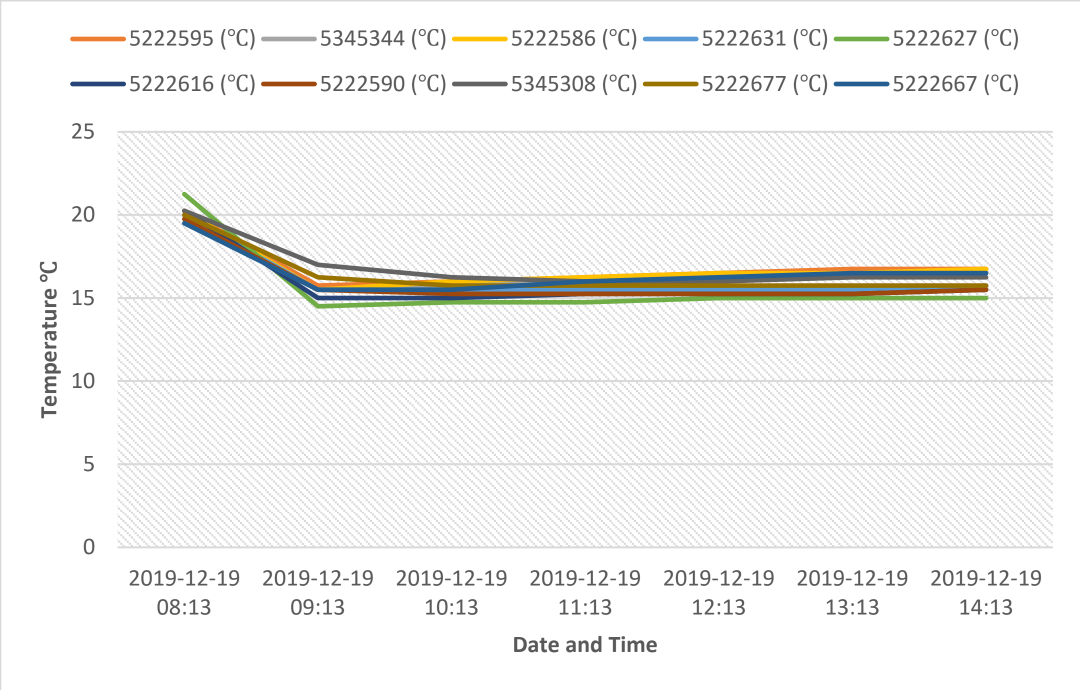


Figure 4.14: Packing stage of Trial 1; Concept A

All 10 devices' temperature readings were above 2 °C, indicating temperature breaks. However, because the fruit was packed just after harvesting and in a packhouse temperature environment of 18 °C, the temperature will be warmer than 2 °C. The next step in the chain is to get the fruit pulp temperature under forced-air cooling within six hours after packing. The median of the 10 devices is 18 °C as per the supply air temperature in the packhouse illustrated in Figure 4.15.

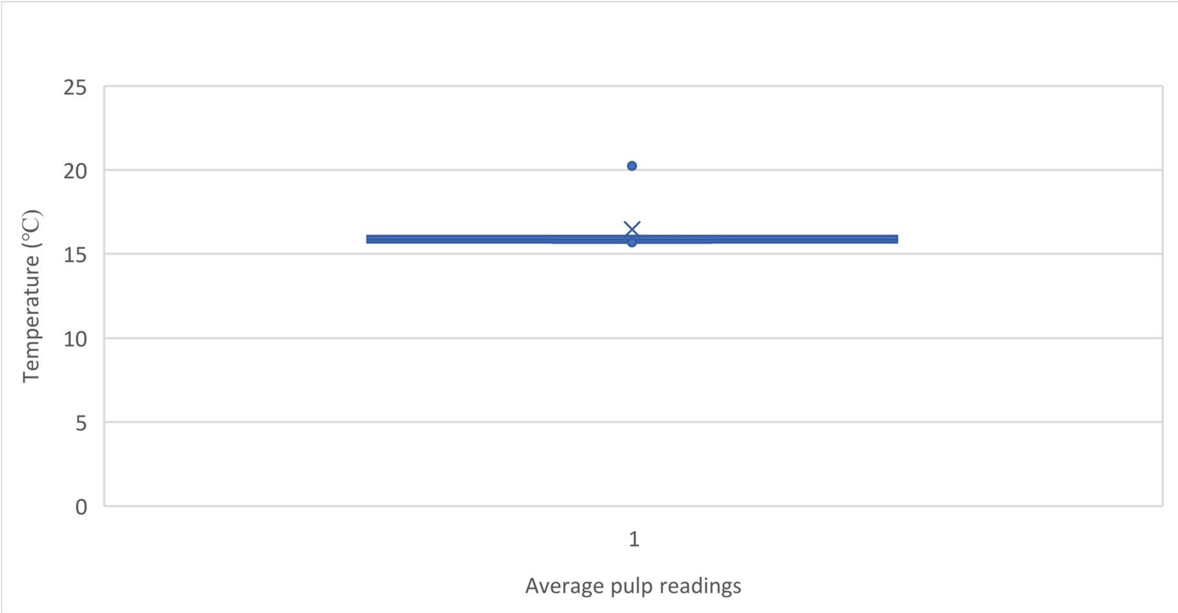


Figure 4.15: Temperature data, packing stage of Concept A, Trial 1

4.6.1.2 Concept A, Trial 1: Transfer stage

Pallets were loaded into a refrigerated truck directly from the holding room at 14:13 on 19 December 2019. The truck reversed into an airlocked loading bay that is part of the holding room. The cooling setpoint of the refrigerated unit of the truck is set at 18 °C, to avoid any risk of condensation.

The transfer period from Packhouse A to Cold Treatment Facility A, taking into consideration the loading and offloading process, took approximately three hours. The temperature data is illustrated in Figure 4.16.

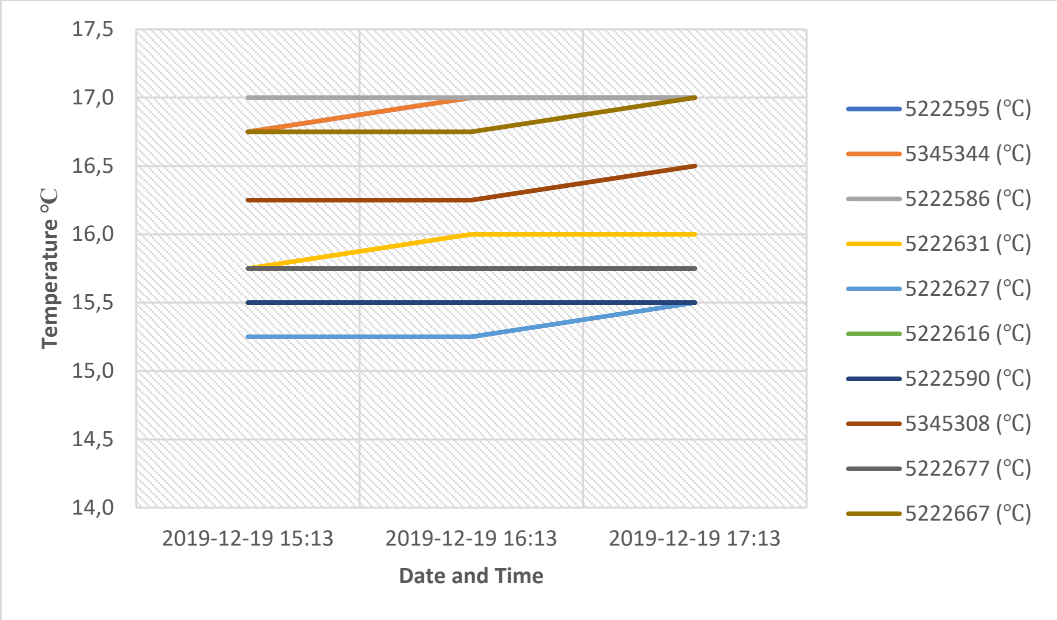


Figure 4.16: Transfer stage of Concept A, Trial 1

All 10 devices indicated temperature breaks because the temperature readings measured were above 2 °C. Some of the devices in the outside cartons had a temperature increase of 0.25 °C due to the movement into the refrigerated truck.

4.6.1.3 Concept A, Trial 1: Forced-air cooling stage

The forced-air cooling tunnels used for the trials in Concept A are registered by the PPECB for the in-land pre-cooling treatment (Steri), which is ideal as the pallets are placed directly in the forced-air cooling tunnels until loading of the container takes place. It took approximately 10 hours from packing until pallets were placed under forced-air cooling. Pallets for Trial 1 were in the tunnel for 64 hours during the forced-air cooling and Steri stages.

The best practice for forced-air cooling is to get the fruit to under -0.5 °C in 48 hours, therefore, the researcher used the 48-hour temperature data from when the pallets were placed under forced-air cooling as illustrated in Figure 4.17.

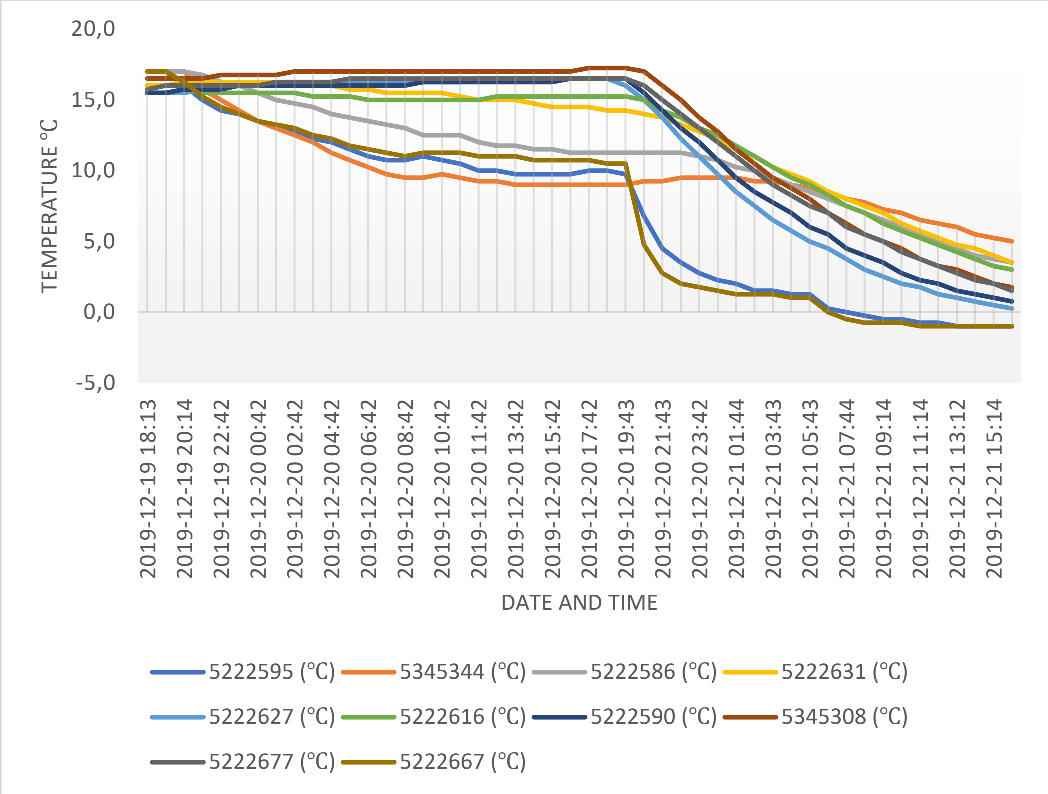


Figure 4.17: Forced- air cooling stage of Concept A, Trial 1

The average temperature at the 48-hour mark was 1.88 ℃.

Cold Treatment Facility A did not close all the openings of the forced-air cooling tunnel at the start of the cooling process. The tunnel was only sealed off after the sample cartons were placed back in the pallets causing a 14-hour delay before the forced-air cooling process could start. Cold Treatment Facility A used a step-down cooling process to bring down the pulp temperature gradually by adjusting the setpoint of the cooling unit. The step-down cooling delays the practice to bring the fruit to under -0.5 °C in 48 hours, but the risk for condensation is limited. Figure 4.18 illustrates a line diagram of average fruit pulp temperature of Concept A, Trial 1.

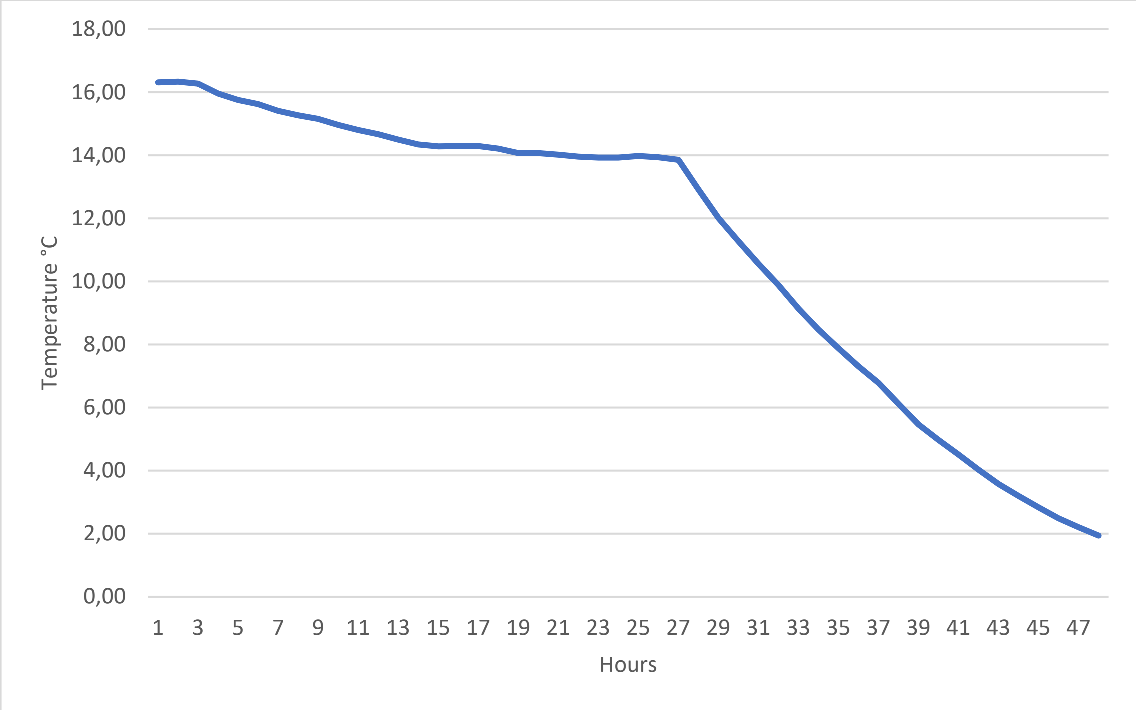


Figure 4.18: Average temperature for forced-air cooling stage of Concept A, Trial 1

Five of the ten devices indicated temperature breaks above 2 °C until the 48-hour force cooling stage was finished. The average temperature of the devices were below 2 °C after 47 hours.

4.6.1.4 Concept A, Trial 1: Steri stage

All grapes destined for China must be forced-air pre-cooled for a minimum of 24 hours. Within the last six hours the fruit must be at a temperature below -0.5 °C and above -1.2 °C. As mentioned in section 4.6.1.3, the grapes were placed under forced-air cooling for 64 hours. For this stage, the researcher used the last 24-hour data of the forced-air cooling tunnel, as illustrated in Figure 4.19.

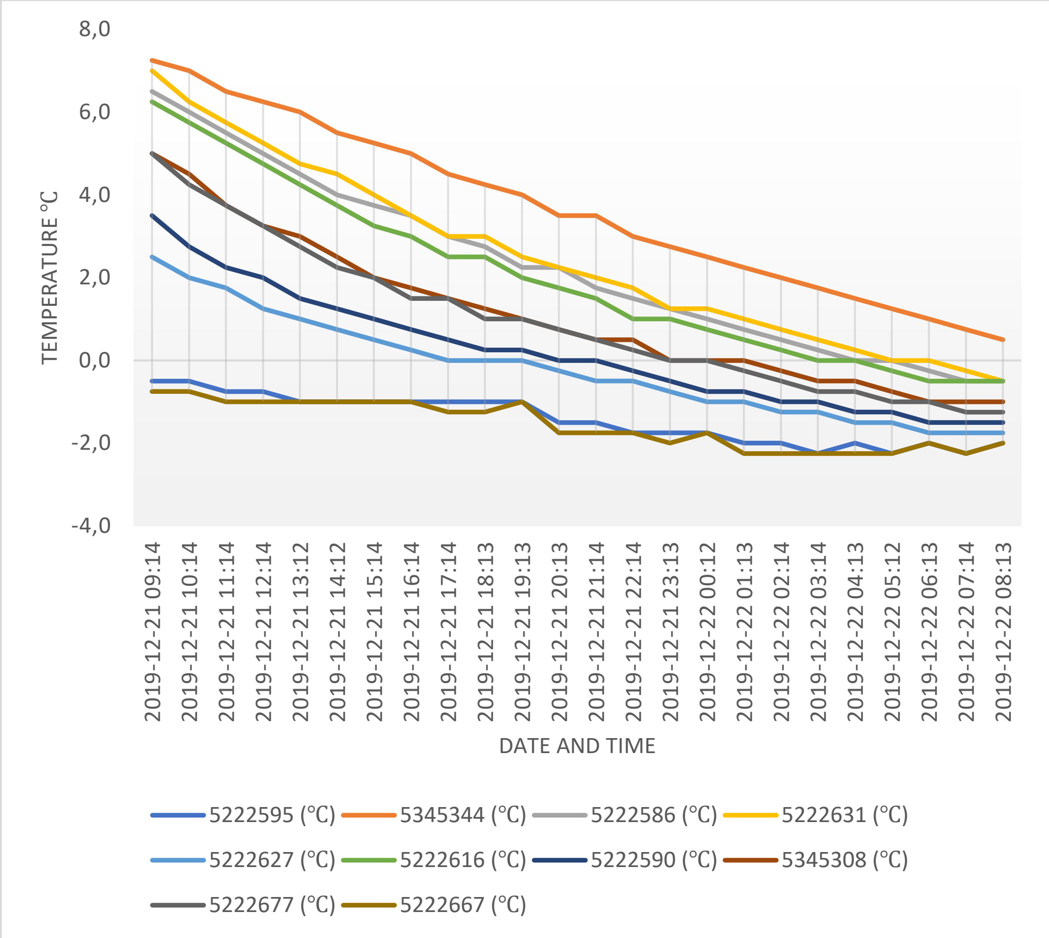


Figure 4.19: Steri stage of Concept A, Trial 1

The devices in the cartons that face the outside of the pallets and tunnel are colder than the devices in the cartons facing the inside of the pallets and tunnel. The temperature data of the last six hours measured with the 10 devices are illustrated in Figure 4.20.

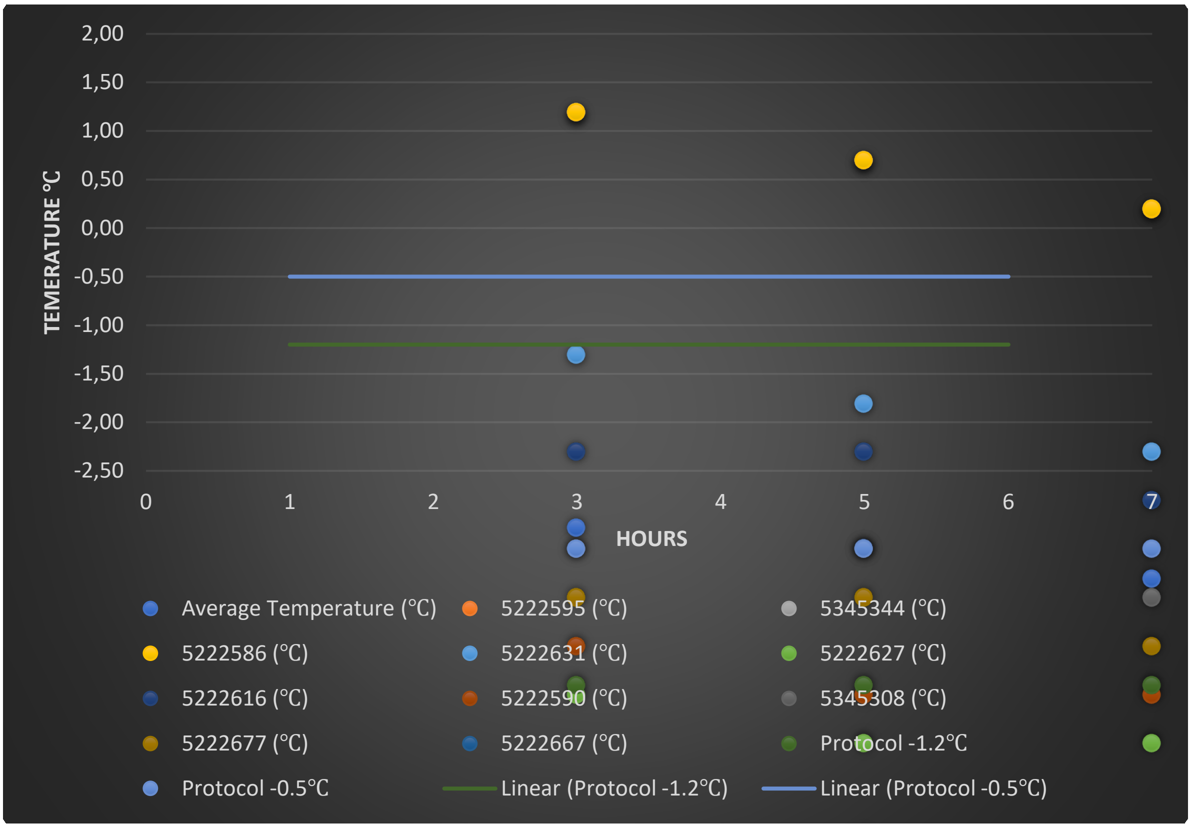


Figure 4.20: Temperature data of the last six hours of the Steri stage of Concept A, Trial 1

Six of the ten devices did not meet the protocol of between -0.5 °C and -1.2 °C for the last six hours of the Steri stage. Four were colder than -1.2 °C and two were warmer than -0.5 °C. The researcher used the pulp sensor data from the cold treatment tunnels as additional information to research the temperature profile of the pallets in the last 24 hours of the Steri process. Six pulp sensors were used in the trial, four on the inside of the tunnel and two on the outside of the tunnel. It is important to note that the pulp sensor is inserted into the grapes and placed in the outer cartons of the pallet. The principle is that if the fruit is measured cold on the inside of the tunnel the whole pallet will be cooled down as the cold air is forced from the outside of the tunnel towards the inside of the tunnel by the suction fans. Due to packing material and if the forced-air cooling tunnel is not correctly sealed, the cold air will take the shortest route, and therefore, the outer cartons of the pallet may be cooler than those at the centre of the pallet. Figure 4.21 illustrates the temperature measured by the pulp sensors for the last 24 hours of the Steri stage.

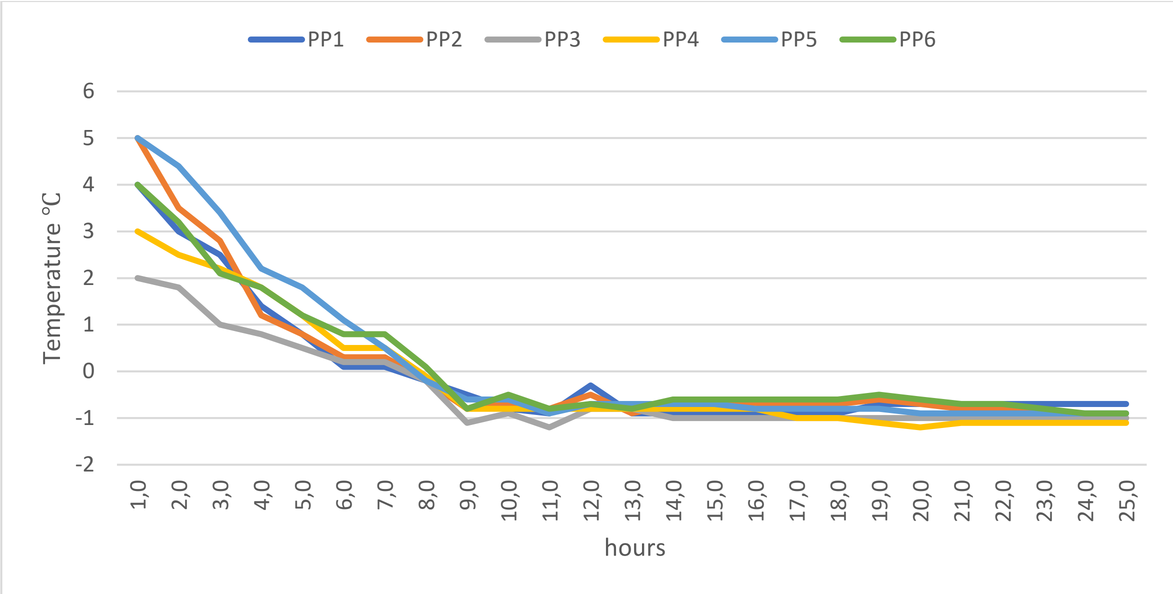


Figure 4.21: 24-hour pulp sensor reading of Concept A, Trial 1

Three temperature breaks were identified where temperature readings were measured as -1.5 °C and colder.

Figure 4.22 illustrates the comparison of the average temperature of the devices used throughout the trial and the average temperature of the fruit pulp sensors used in the cold treatment tunnels.

The average of the devices supplies an overall temperature profile of the centre of the three pallets measured. The average of the pulp sensors supplies a temperature profile of the outside layer of six pallets, four cartons facing the inside of the tunnel and two cartons facing the outside of the tunnel. All these devices and sensors were in the same tunnel, namely tunnel 25.

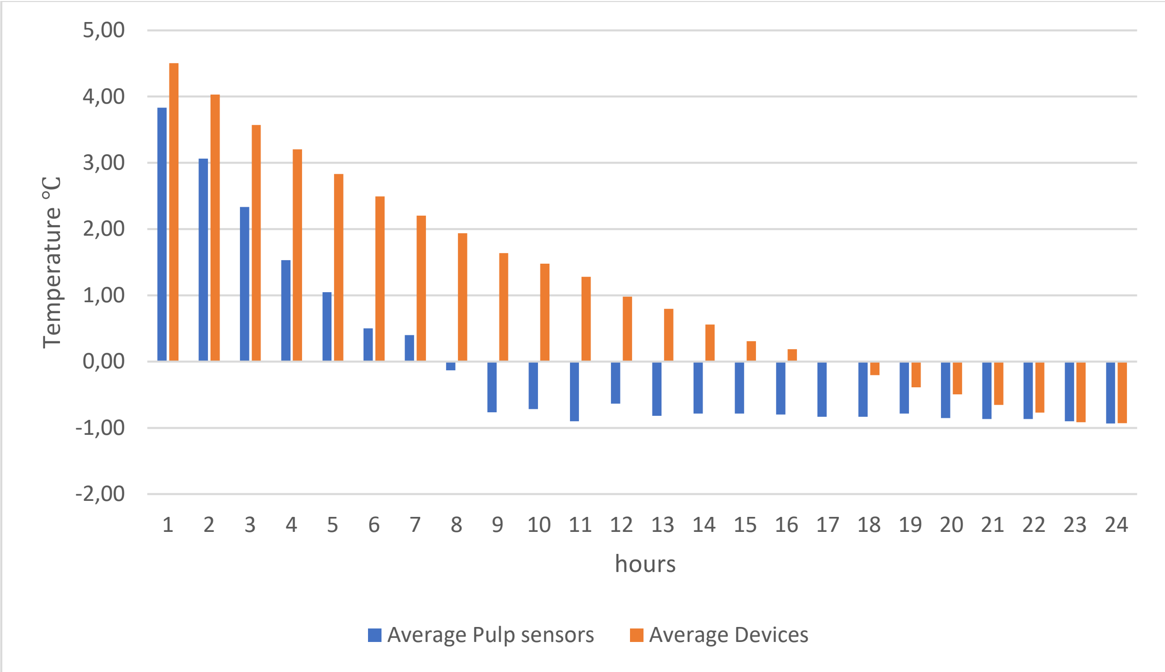


Figure 4.22: Average temperature data measured by pulp sensors and devices used in Trial 1, Concept A

The centre pallet temperature influences the tunnel temperature and in the last six to four hours the temperature starts stabilising before the next stage of the process takes place.

4.6.1.5 Concept A, Trial 1: Loading stage

Pallets were loaded into container number SZLU9551666 at 09:30 on 22 December 2019. The loading process took 40 minutes as per the loading protocol.

Two temperature breaks and two temperature spikes occurred during this stage. The spikes occurred due to the movement from the tunnels into the container, the temperature went from colder than -1.5 °C to warmer than -1.5 °C within less than 90 minutes Table 4.3 depicts the temperature data of the 10 devices used in the trial, as well as their average temperature.

Table 4.3: Temperature data readings of the loading stage of Concept A, Trial 1

Date and Time	Average Temperature (℃)	5222595 ( )	5345344 ( )	5222586 ( )	5222631 ( )	5222627 ( )	5222616 ( )	5222590 ( )	5345308 ( )	5222677 ( )	5222667 ( )
2019-12-22 09:14	-0.93	-2.0	0.5	-0.5	-0.5	-1.75	-0.5	-1.5	-1	-1.25	-2
2019-12-22 10:12	-0.77	-1.3	0.5	-0.5	-0.5	-1.2	-0.5	-1.5	-1	-1.25	-1.5

4.6.1.6 Concept A, Trial 1: Stack and shipping stage

Figure 4.23 illustrates the temperature data during the stacking and voyage stage.

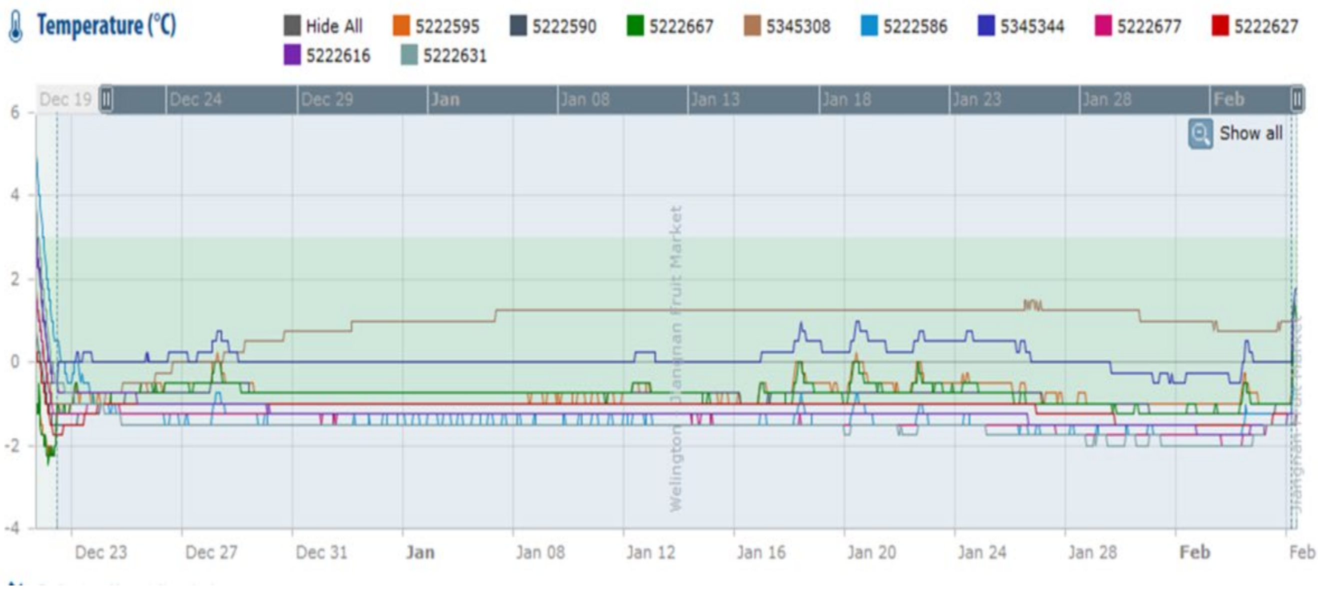


Figure 4.23: Stack and sea voyage stage of Concept A, Trial 1

No temperature breaks occurred during the voyage.

4.6.2 Concept A, Trial 2

Trial 2 was conducted on pallets destined for China. Twelve devices were divided into three pallets. Pallet ID 460091600151957099 had four devices, namely 5244942, 5345082, 5244994 and 5244915. Pallet ID 460091600151957082 had four devices, namely 5345081, 5345004, 5345091 and 5345019. Pallet ID 460091600151957129 had four devices, namely 5345339, 5244941, 5244981 and 5244916.

Devices were inserted at 08:00 on 15 January 2020 at Packhouse A. The consignment containing pallet ID's 460091600151957099, 460091600151957082 and 460091600151957129 arrived at Cold Treatment Facility A at 18:59 on 15 January 2020. Pallets were loaded into the container on 20 January 2020 at 18:30.

Figure 4.24 illustrates the average temperature data of Trial 2 of Concept A. Figure 4.25 illustrates the average temperature data of the 12 devices used in Trial 2 of Concept A.

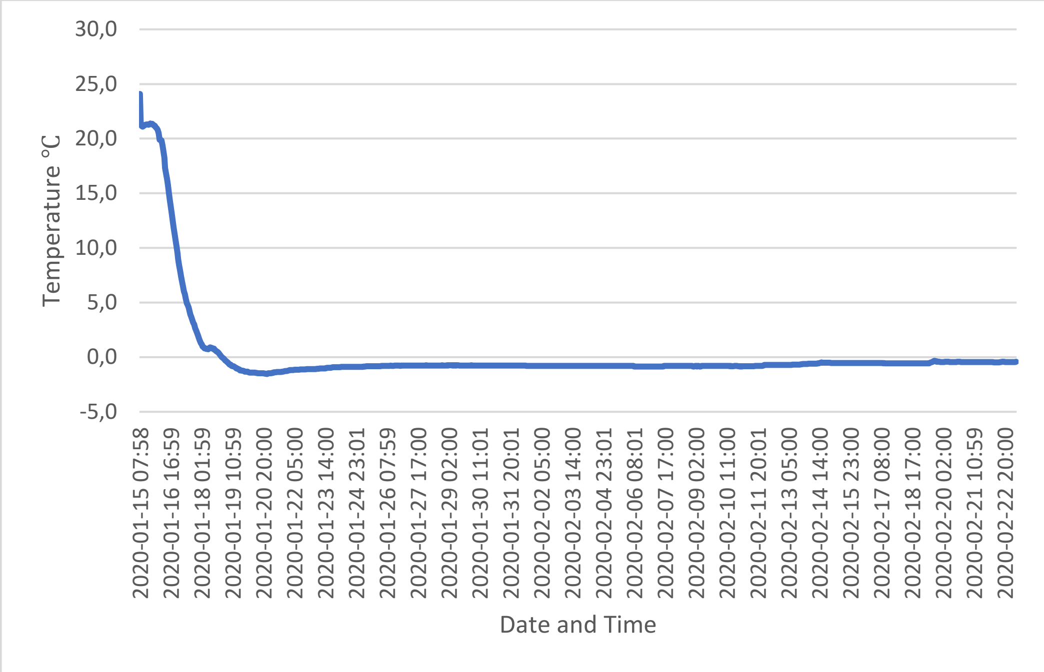


Figure 4.24: Average temperature data for Concept A, Trial 2

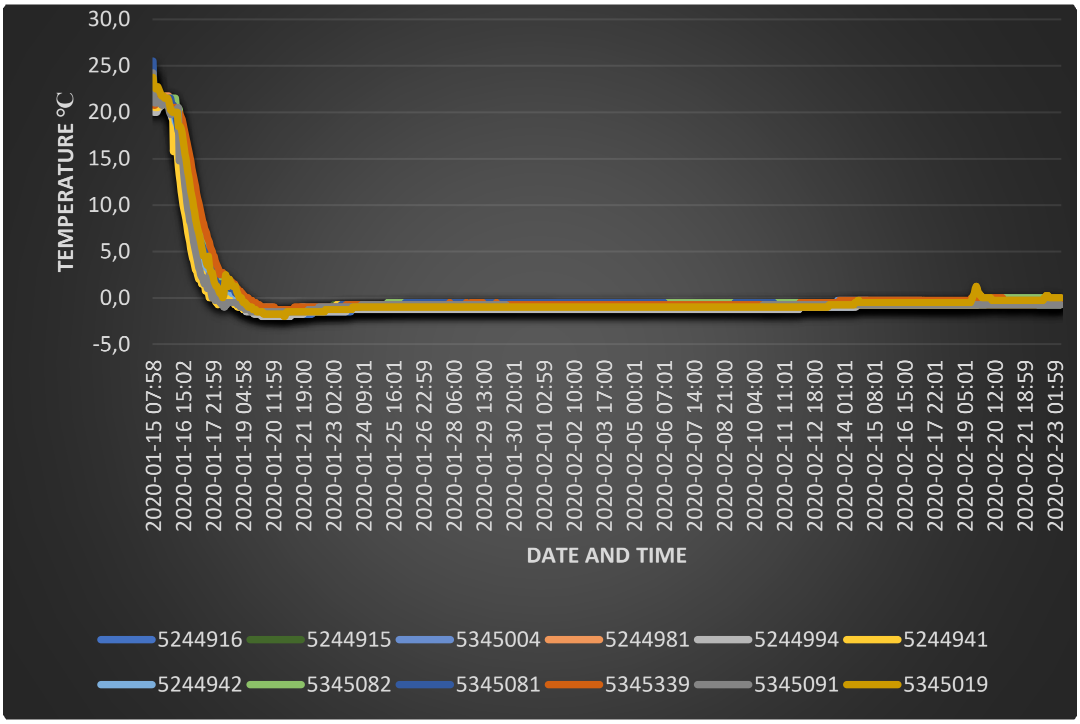


Figure 4.25: Temperature data of Trial 2, Concept A

4.6.2.1 Concept A, Trial 2: Packing stage

Sugrathirteen (Midnight Beauty) grapes were packed on 15 January 2020 at Packhouse A. Sugrathirteen is a large berry, black seedless variety (Sunworld, 2020:5). The grapes were packed in B04I cartons, 180 cartons palletised per pallet base.

The researcher inserted the devices at 08:00 while the pallets were palletised, after which the pallets were moved to a holding area that was set at 18 °C. Pallets were kept in the holding area until 14:40. The packing and holding stage took approximately seven hours before pallets were loaded into a refrigerated truck. Figure 4.26 illustrates the temperature data during the packing stage of Concept A, Trial 2.

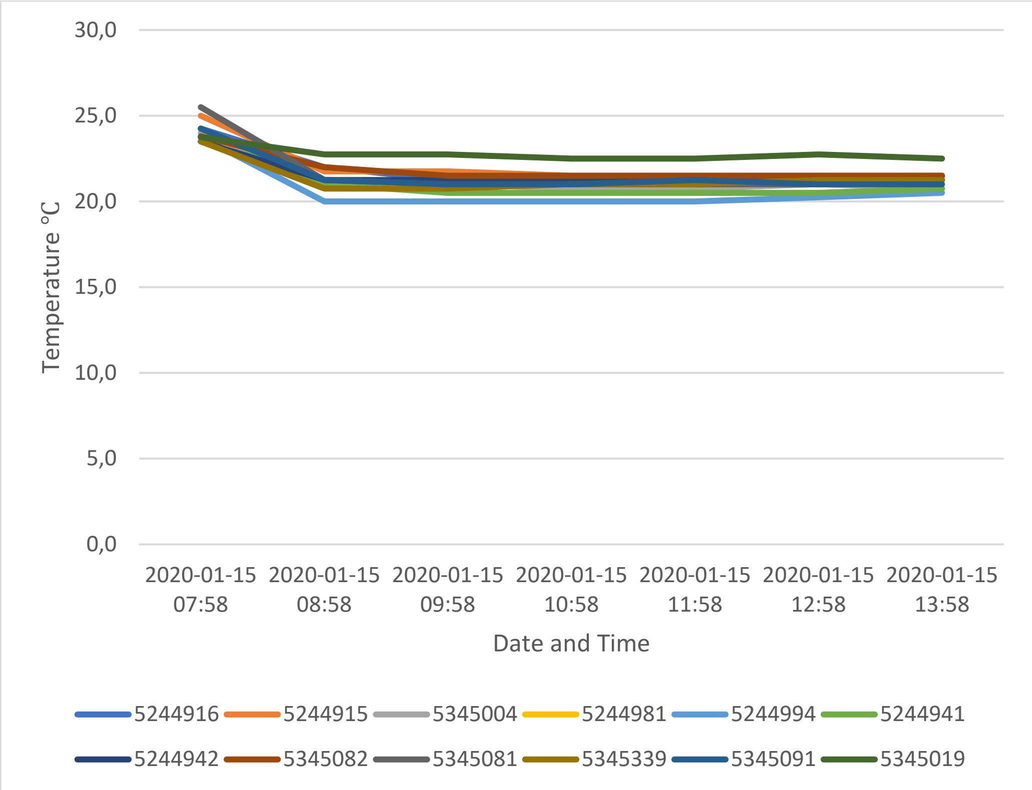


Figure 4.26: Packing stage of Concept A, Trial 2

All 12 devices were warmer than 2 °C, indicating a temperature break. However, the controlled temperature of the packhouse was between 18 °C and 25 °C, and therefore, the fruit pulp temperature is between 20 °C and 25 °C.

4.6.2.2 *Concept A, Trial 2: Transfer stage*

On 15 January 2020 at 14:40, the pallets were loaded into a refrigerated truck directly from the holding room, using an airlocked loading bay. The refrigeration unit of the truck was set at 18 °C.

For Concept A, Trial 2, the transfer stage from Packhouse A to Cold Treatment Facility A took four hours, including the loading and offloading processes.

Figure 4.27 illustrates the temperature data of the transfer stage.

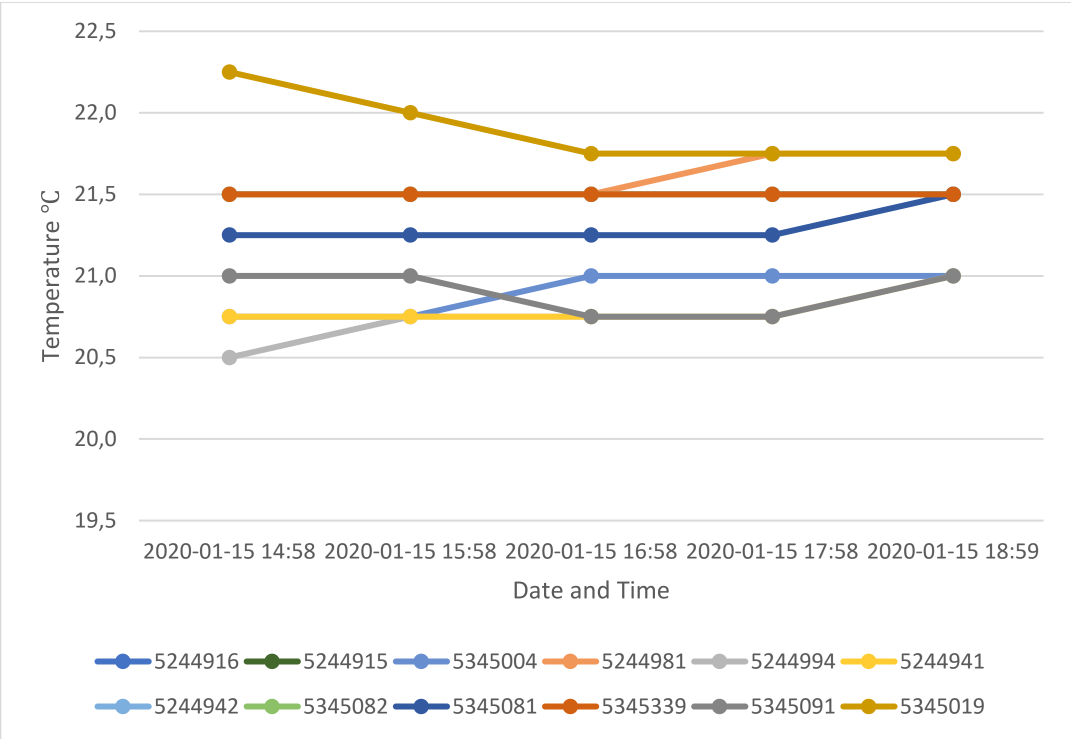


Figure 4.27: Temperature data of the transfer stage, Concept A, Trial 2

All 12 devices were warmer than 2 °C for longer than 90 minutes, and therefore, temperature breaks were identified during the transfer stage of Concept A, Trial 2.

4.6.2.3 *Concept A, Trial 2: Forced-air cooling stage*

Pallets were placed directly in the forced-air cooling tunnel and stayed in the tunnel until the loading of the container took place as per Trial 1 of Concept A.

Pallets of Trial 2 were in the forced-air cooling tunnel for 119 hours before the container was loaded.

Figure 4.28 illustrates the temperature data of the first 48 hours of forced-air cooling, as the first 48 hours is seen as best practice to get fruit under -0.5 °C. Cold Treatment Facility A used the step-down cooling process, but this process delays getting the fruit to under -0.5 °C in 48 hours. Not one of the devices were under -0.5 °C in 48 hours.

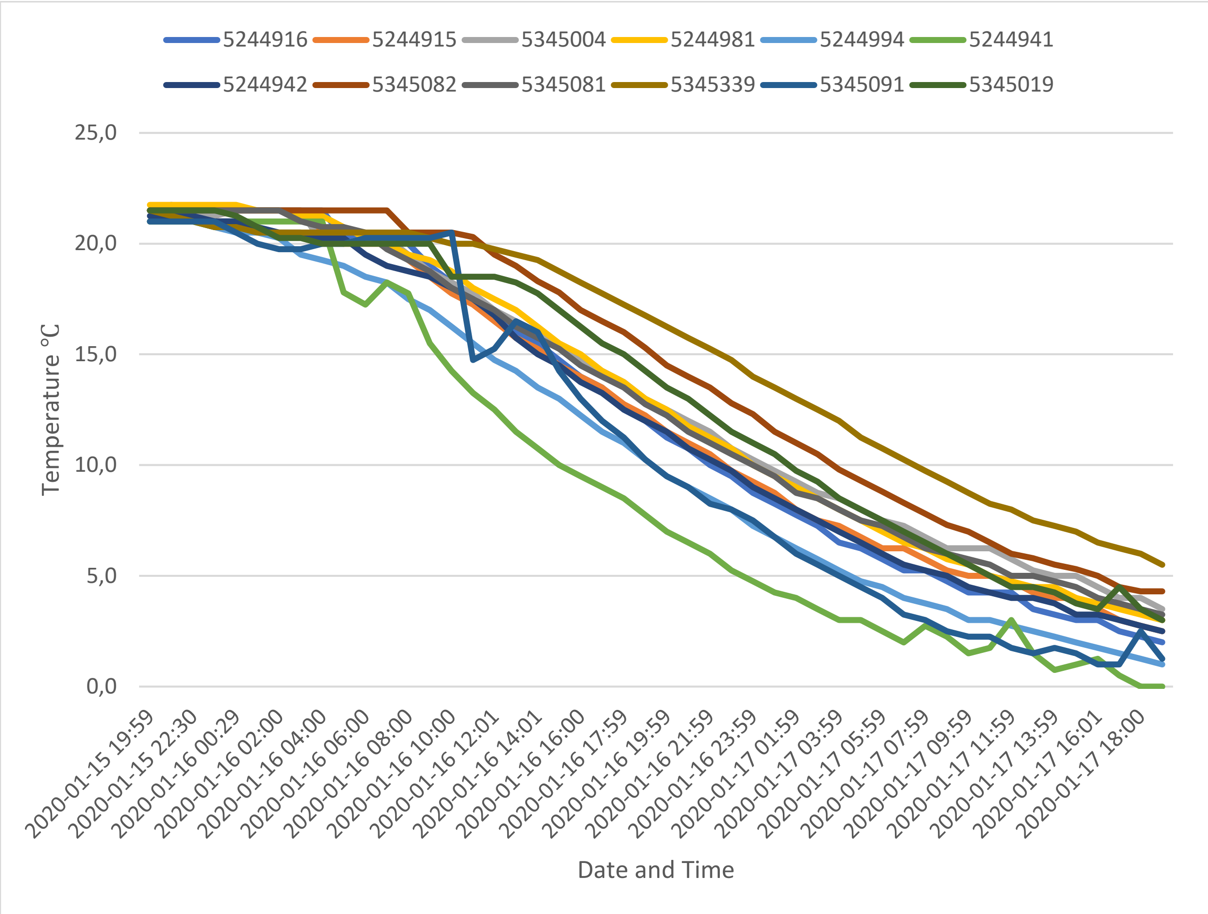


Figure 4.28: 48-hour force-cooling stage of Concept A, Trial 2

Figure 4.29 illustrates the temperature data of the 95 hours from when the forced-air cooling stage started to when the Steri stage starts.

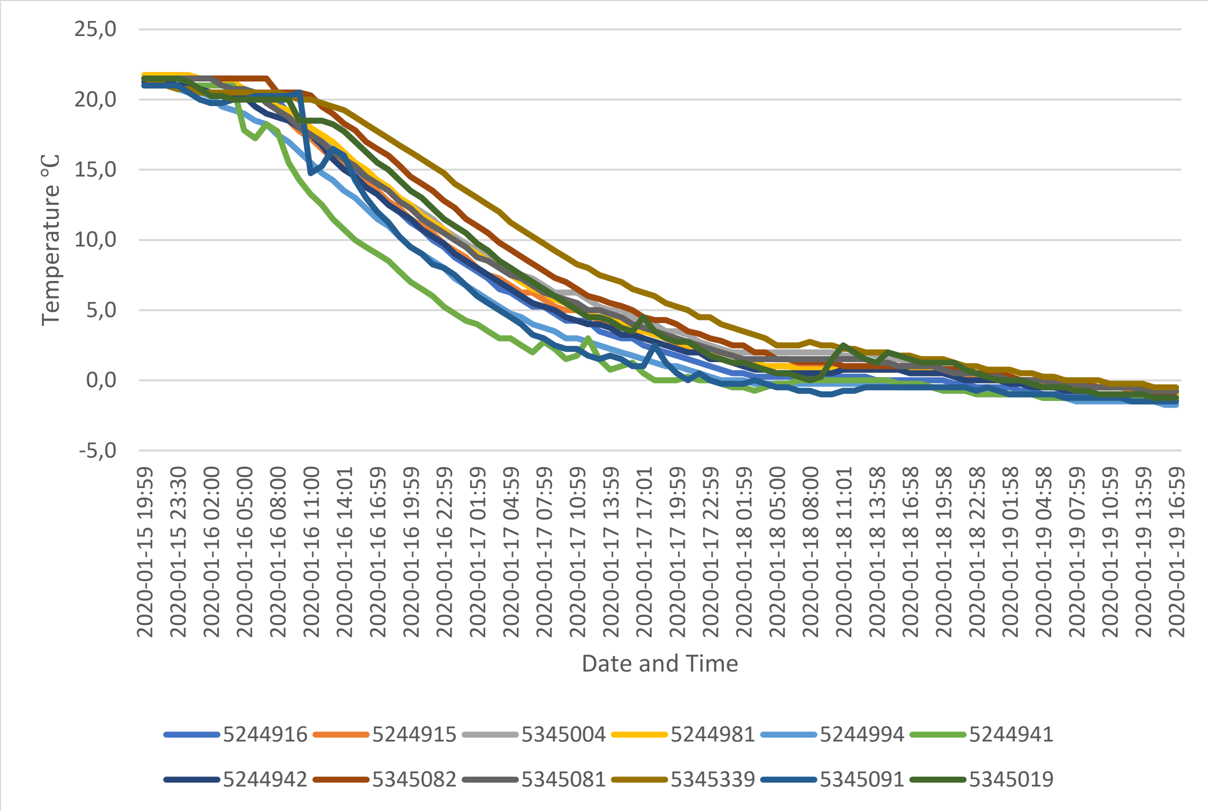


Figure 4.29: Forced-air cooling stage of Concept A, Trial 2

All 12 devices indicated temperature breaks for 56 hours until the temperature decreased below 2 °C. In addition, three temperature spikes were indicated due to phytosanitary sample cartons being placed back onto the pallets, temperature monitors opening the tunnel to take physical temperature measurements and defrosting of cooling equipment.

The average temperature breaks of the 12 devices are illustrated in Figure 4.30.

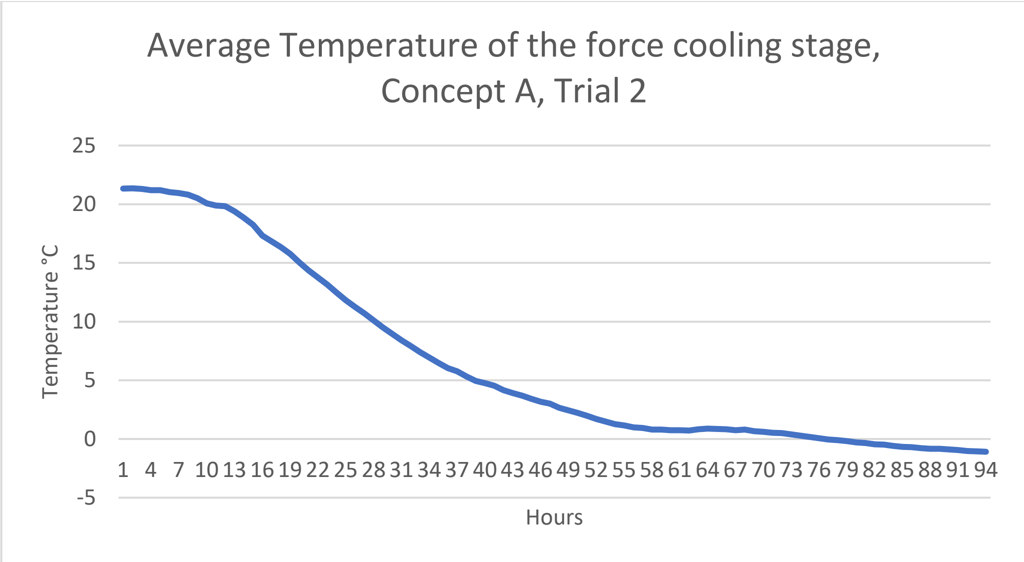


Figure 4.30: Average temperature of the force-cooling stage, Concept A, Trial 2

It took the average temperature 56 hours to decrease below 2 °C.

4.6.2.4 Concept A, Trial 2: Steri stage

The pallets were loaded for China; therefore, the pallets must be in Steri for a minimum of 24 hours. The researcher used the last 24-hours temperature data of the Steri stage before the loading stage started (see Figure 4.32).

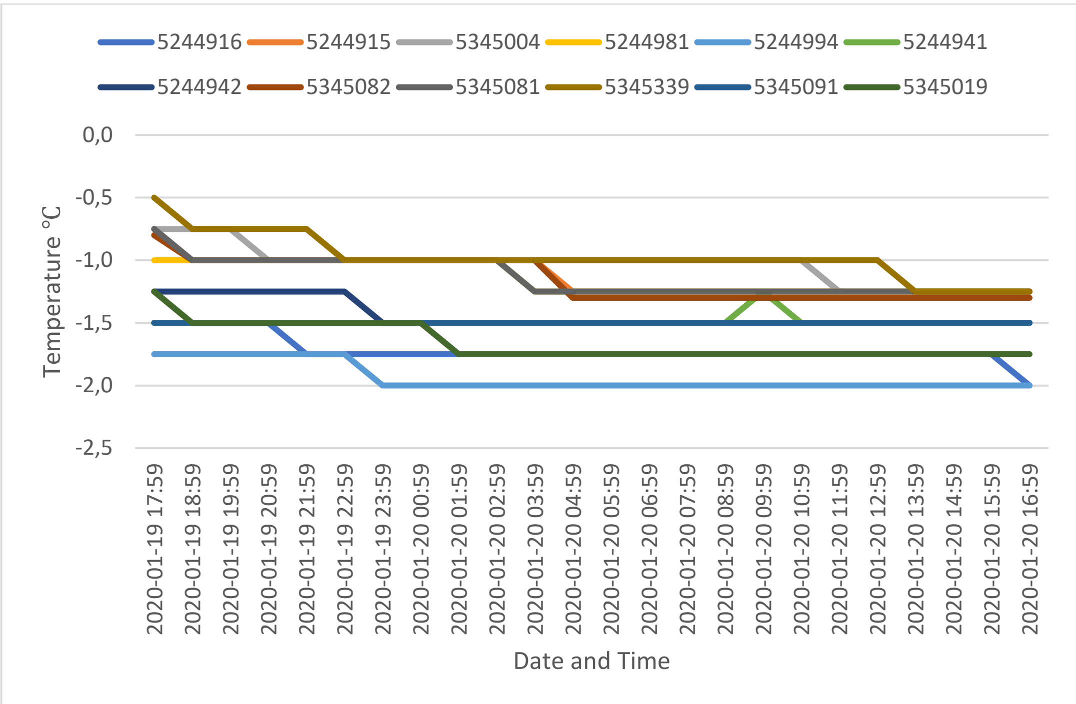


Figure 4.32: Temperature data of the Steri stage, Concept A, Trial 2

Six temperature devices indicated temperature breaks that got too cold. The devices on the outside carton layers were colder than the devices in the centre cartons of the pallet. Figure 4.33 illustrates a scatter chart of the last six hours of the Steri stage where the pallets must be between -0.5 °C and -1.2 °C.

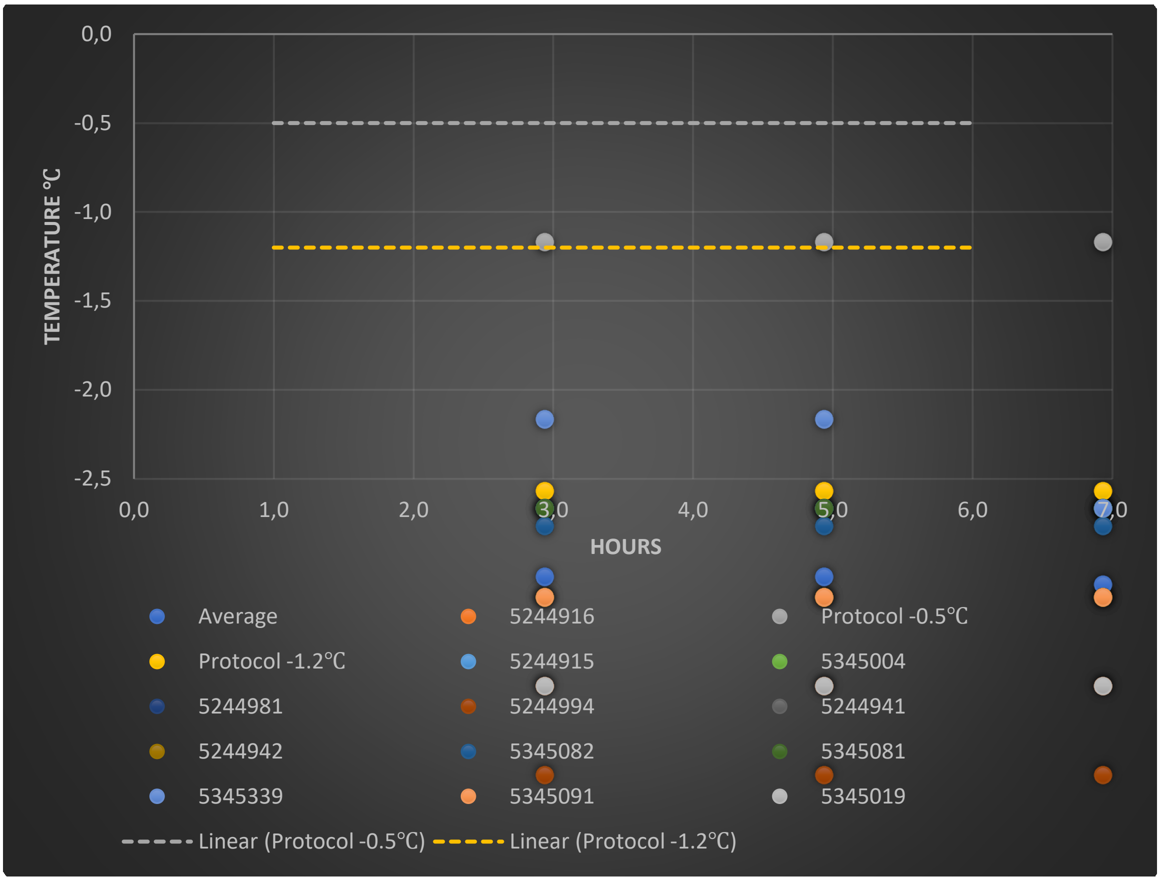


Figure 4.33: Last six hours of the Steri stage of Concept A, Trial 2

All 12 devices used were out of protocol, being colder than -1.2 °C. The PPECB allows the setpoint of a room to be set to -1. °C to reach the pulp temperatures of -1.2 °C. With the setpoint of a room set at -1.5 °C, the supply air of the tunnel deviates approximately between -2 °C and -1 °C due to the valves of the evaporator opening and closing to reach the desired temperature of -1.5 °C as per the setpoint. In Trial 2, the pallets were under forced-air cooling for 119 hours, thoroughly cooling the fruit. The fruit started to reach the temperature of the supply air due to the thorough cooling.

Six fruit pulp sensors were used to supply the PPECB with a temperature printout of the last 24 hours before the fruit could be loaded for China. The researcher used the same pulp sensor data to add additional data to the Steri stage of Concept A, Trial 2. This is illustrated in Figure 4.34, a line diagram of the pulp sensor data.

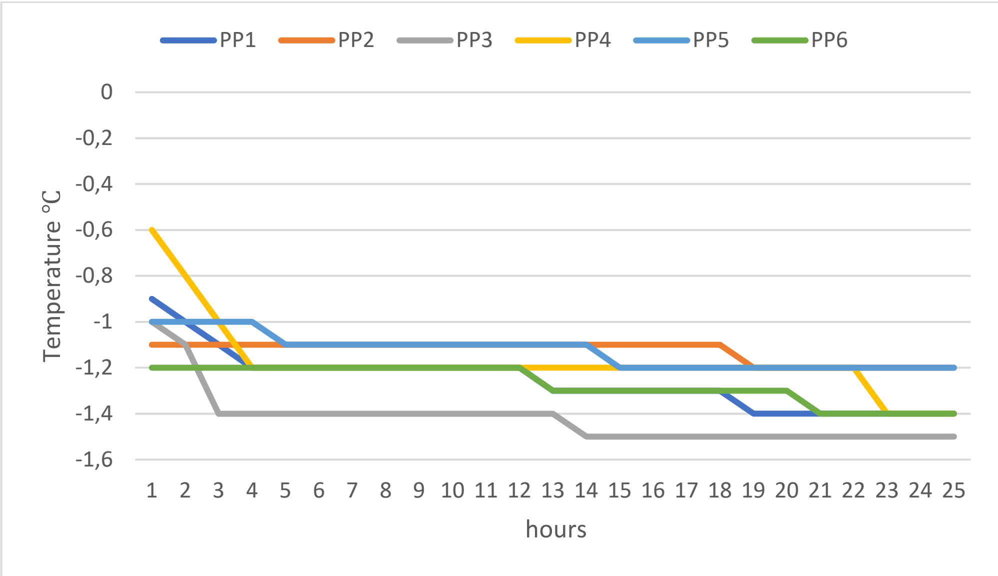


Figure 4.34: 24-hour pulp sensor data of Concept A, Trial 2

One temperature break was identified by measuring -1.5 °C for longer than 90 minutes.

Figure 4.35 illustrates a cluster chart identifying the similarity between the averages of the temperature data measured with the devices and pulp sensors of Concept A, Trial 2.

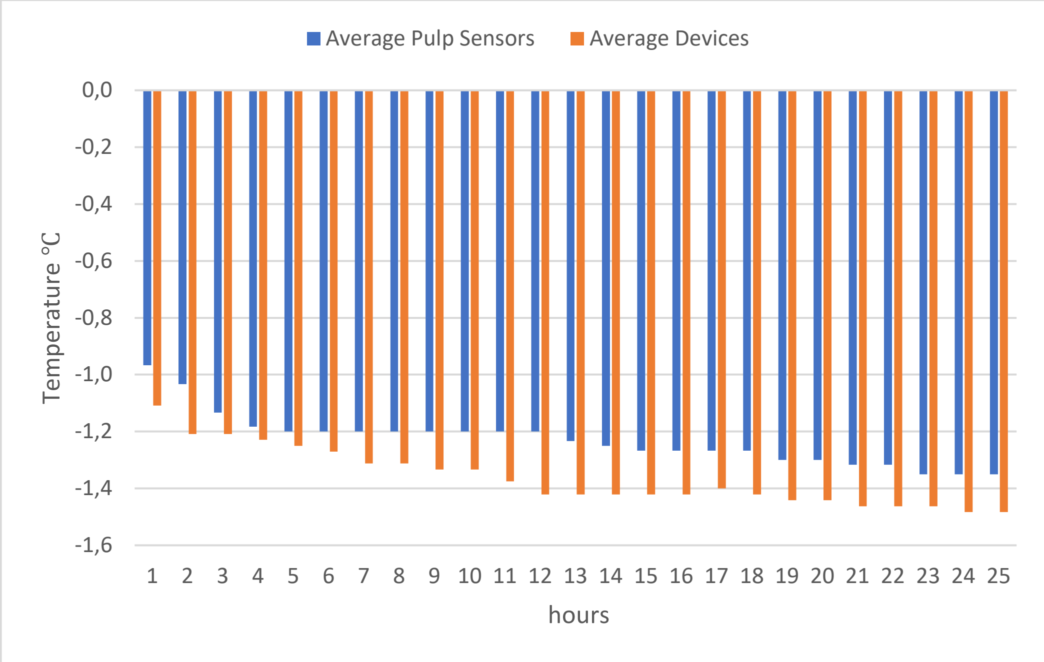


Figure 4.35: Steri stage of Concept A, Trial 2

4.6.2.5 Concept A, Trial 2: Loading stage

The loading process started at 18:30 and finished at 19:00 on 20 January 2020. Pallets were loaded into container number TEMU9625437. Six devices indicated temperature breaks by measuring -1.5 °C and colder, indicated in Table 4.4.

Table 4.4: Temperature data of the loading stage for Concept A, Trial 2.

Date and Time	5244916	5244915	5345004	5244981	5244994	5244941	5244942	5345082	5345081	5345339	5345091	5345019
2020-01-20 17:59	-2.0	-1.3	-1.3	-1.3	-2.0	-1.5	-1.5	-1.3	-1.3	-1.3	-1.5	-1.8
2020-01-20 19:00	-1.8	-1.3	-1.3	-1.3	-2.0	-1.5	-1.5	-1.3	-1.3	-1.3	-1.5	-1.8

4.6.2.6 Concept A, Trial 2: Stacking and shipping stage

The container was transported from Cold Treatment Facility A to the stack at the Port of Ngqura. The container arrived at the stack on 21 January 2020 and was monitored for three days until it was loaded onto the vessel on 24 January 2020.

On 14 February 2020, the container was discharged in the Port of Hong Kong and was cleared by customs on 19 February 2020. The container arrived at Guangzhou’s Jiangnan market in

China on 19 February 2020. Figure 4.36 is a map indicating where the Jiangnan market is situated.

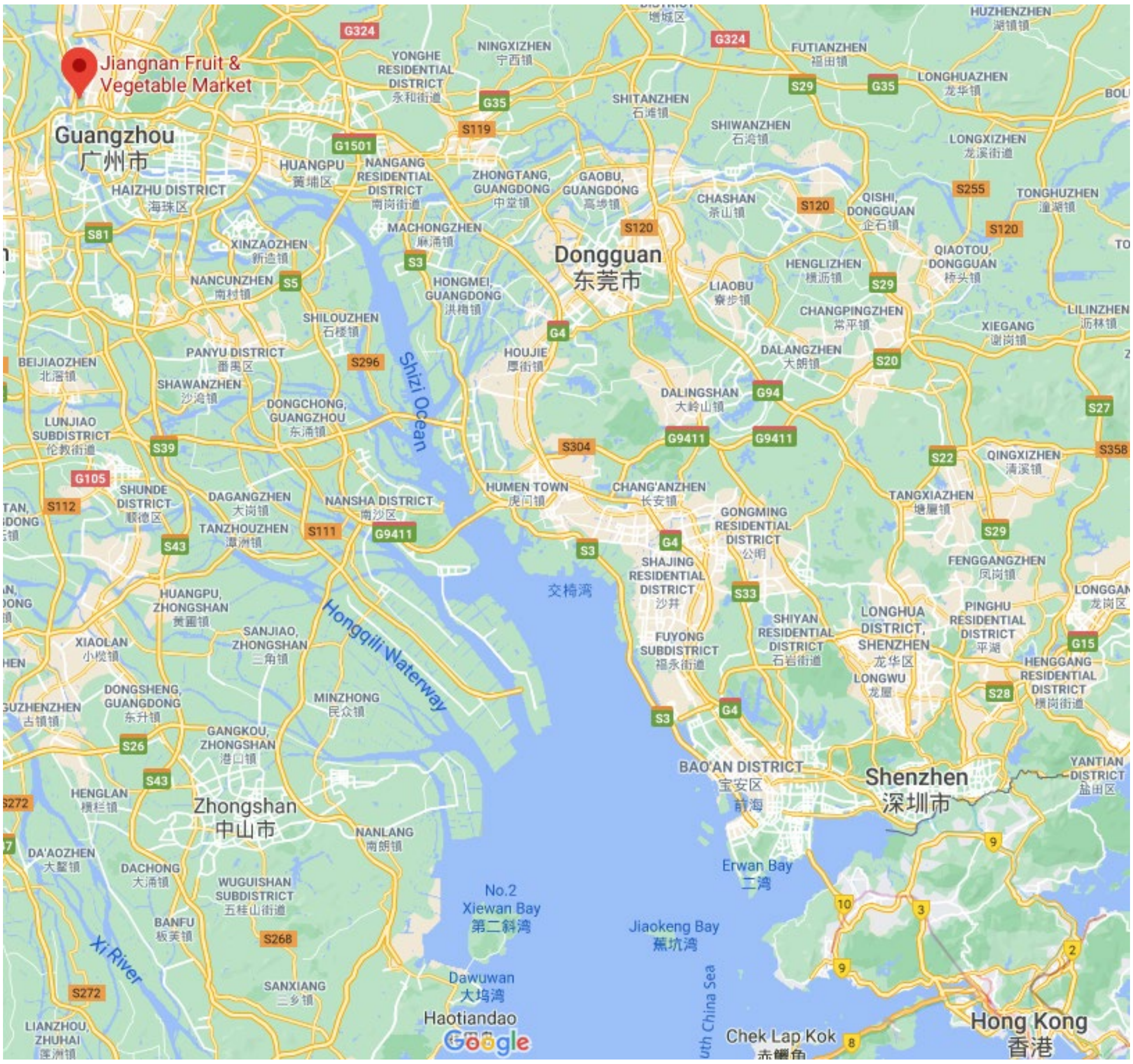


Figure 4.36: Map indicating where the Jiangnan market is situated

Source: Google Maps (2020)

An Xsense receiver installed at the Jiangnan Market retrieved the temperature data.

All data were retrieved up to 23 February 2020 when the fruit left the Jiangnan Market to the different retailers. The temperature data from when the container left Cold Treatment Facility A to when the pallets left the Jiangnan Market are depicted in Figure 4.37.

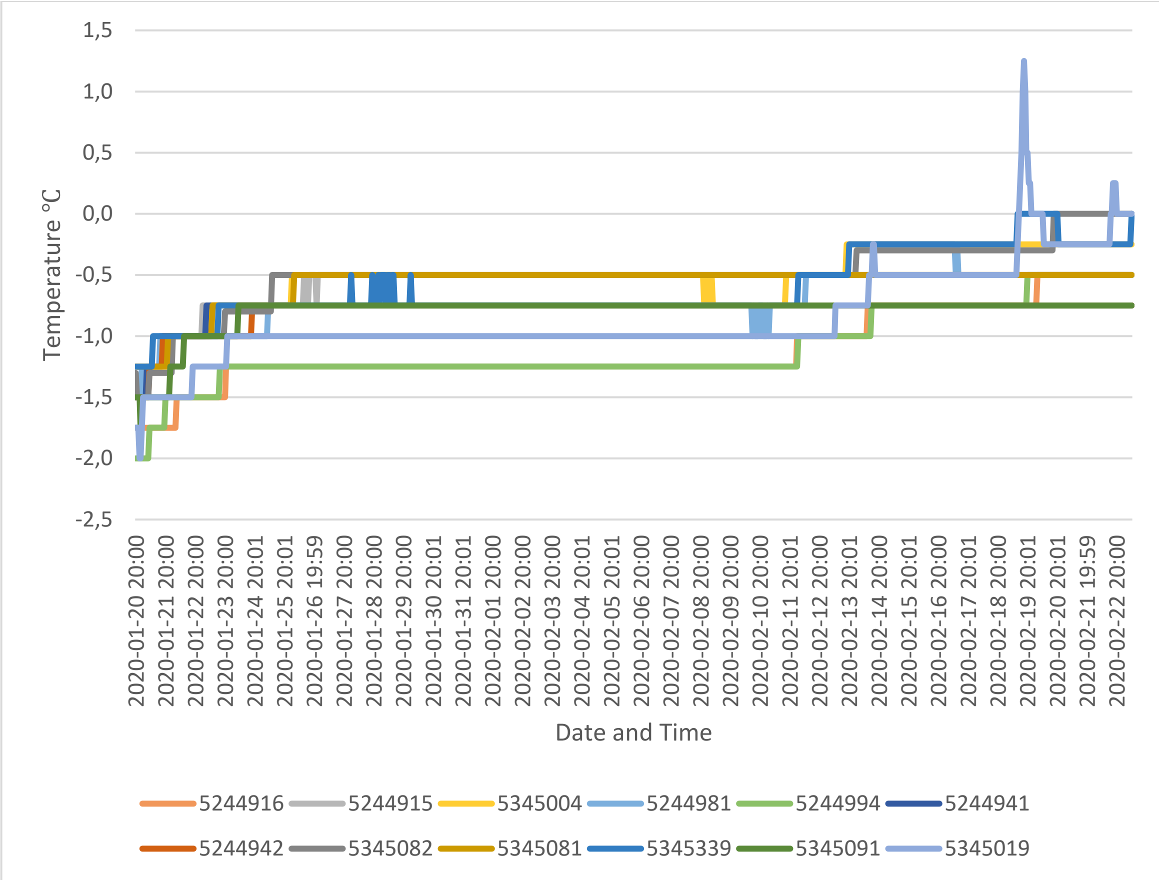


Figure 4.37: Temperature data from when container left Cold Treatment Facility A until the pallets left Jiangnan Market to the retailers. Concept A, Trial 2

The container setpoint is set at -1 °C, and therefore, the pulp temperature will increase proportionately to the air temperature. Grapes must be under cold treatment for 20 days after the container has been loaded for China. The 20th day was 9 February 2020 at 19:00 for Concept A, Trial 2.

Three temperature breaks were identified in the start of the stage, but a clear indication of pulp temperature increase can be seen in Figure 4.37.

For the 20 cold treatment days, the fruit never became warmer than -0.5 °C and colder than -1.2 °C due to the supply air of the container that fluctuates to reach the setpoint of -1 °C.

On 14 February 2020, the container was discharged in Hong Kong and the setpoint of the container was amended to -0.5 °C, causing a slight increase in the pulp temperature.

On 19 February 2020, the pallets were offloaded at the Jiangnan Market, causing a slight increases in temperature of the three devices that were in the outside cartons of the pallets.

For additional information, the researcher used Sensitech TempTale GEO number GKJ11008E1 for monitoring the ambient air temperature during the stacking and sea voyage stage. TempTale GKJ11008E1 monitored the air temperature at the door of the container and was inserted into a carton facing the door of the container of pallet ID 460091600151957006.

The minimum air temperature measured was -0.1 °C during the voyage. Figure 4.38 illustrates the ambient air temperature and light measured by TempTale GKJ11008E1, indicating when the container was opened and the TempTale was exposed to light. One temperature spike was identified by the GEO temptale on 14 February 2020 when the container was discharged in Hong Kong and the temperature increased to 3.8 °C.

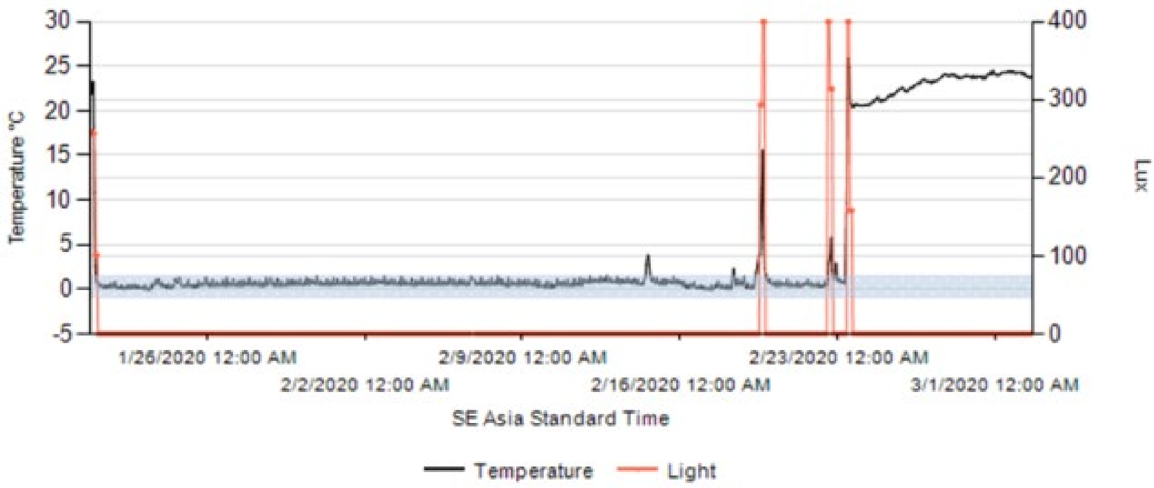


Figure 4.38: Ambient air temperature measured for Concept A, Trial 2

4.6.3 Concept A, Trial 3

Trial 3 was conducted on pallets destined for China, with 12 devices divided between three pallets. Pallet ID 460091601516358766 had four devices, namely 5345362, 5345072, 5345074 and 5345358. Pallet ID 460091601516358742 had four devices, namely 5245002, 5345383, 5345335 and 5345379. Pallet ID 460091601516358759 had four devices, namely 5345376, 5345009, 5345310 and 5244971.

The devices were inserted at 09:00 on 15 January 2020 at Packhouse A. The consignment containing pallet IDs 460091601516358766, 460091601516358742 and 460091601516358759 arrived at Cold Treatment Facility A at 18:59 on 15 January 2020. Pallets were loaded into the container on 20 January 2020 at 19:47.

Figure 4.39 illustrates the average temperature data of Concept A, Trial 3.

Figure 4.40 illustrates the temperature data of the 12 devices used in Trial 3 of Concept A.

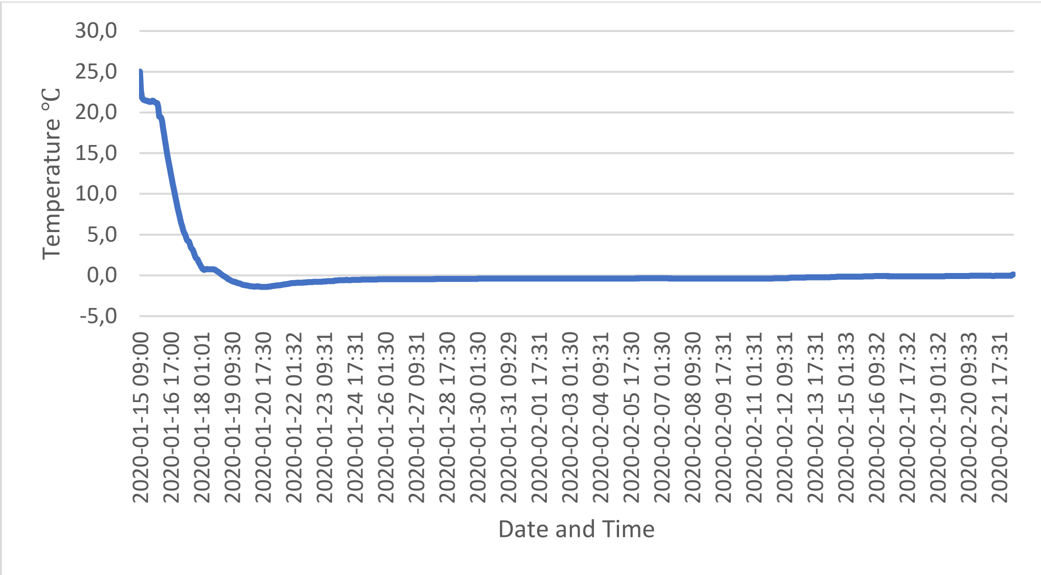


Figure 4.39: Average temperature for Concept A, Trial 3

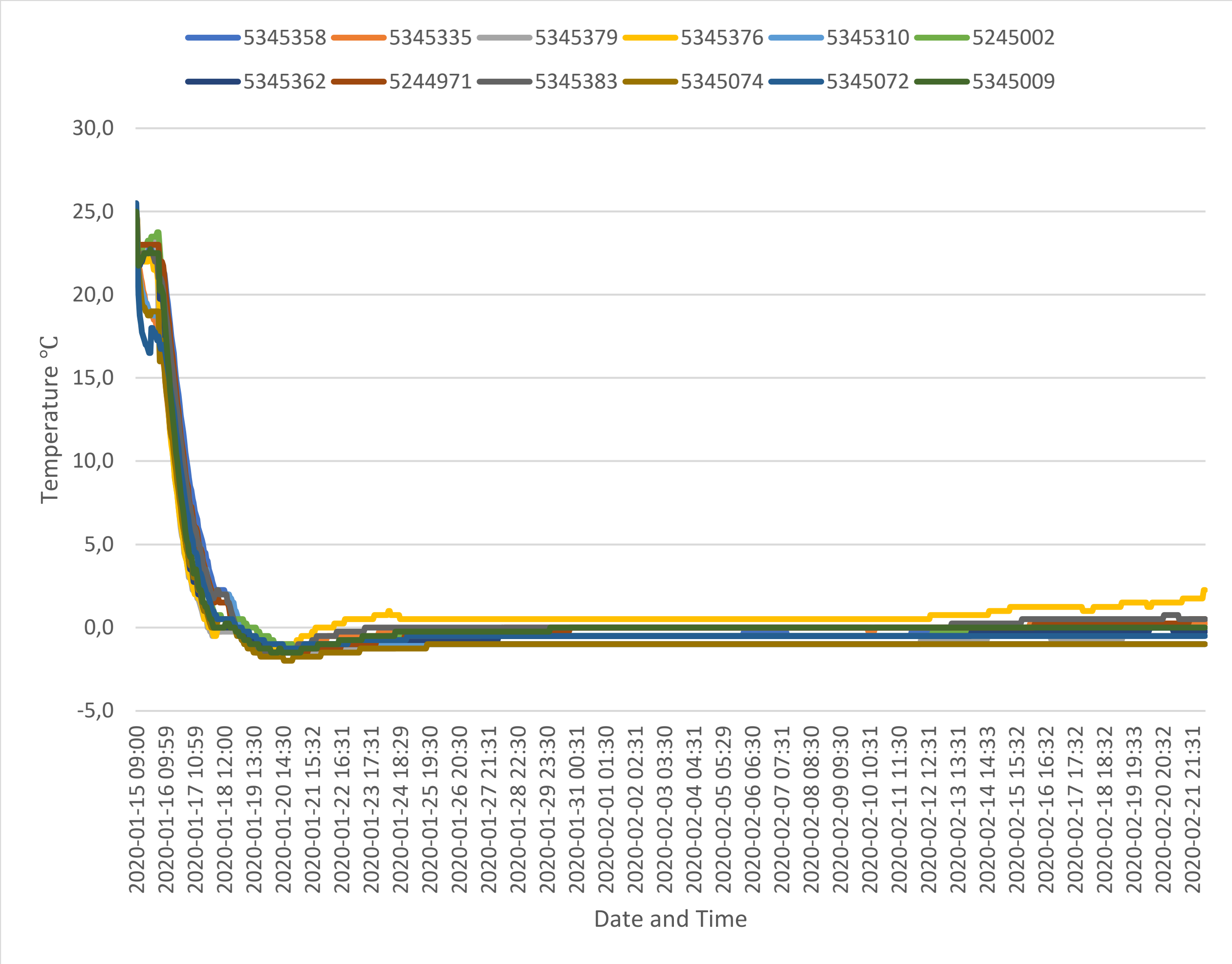


Figure 4.40: Temperature data of 12 devices measured for Concept A, Trial 3

4.6.3.1 Concept A, Trial 3: Packing stage

Sugrathirteen (Midnight Beauty) grapes were packed on 15 January 2020 at Packhouse A. The grapes were packed in B04I cartons, 180 cartons palletised per pallet base, the same as Trial 2.

The researcher inserted the devices at 09:00 while the pallets were palletised. Thereafter, the pallets were moved to a holding area that was set at 18 °C. Pallets were kept in the holding area until 14:40. The packing and holding stage took approximately five hours before pallets were loaded into a refrigerated truck. Pallets were loaded into the same truck as the pallets from Trial 2.

Figure 4.41 illustrates the temperature data during the packing stage of Concept A, Trial 3.

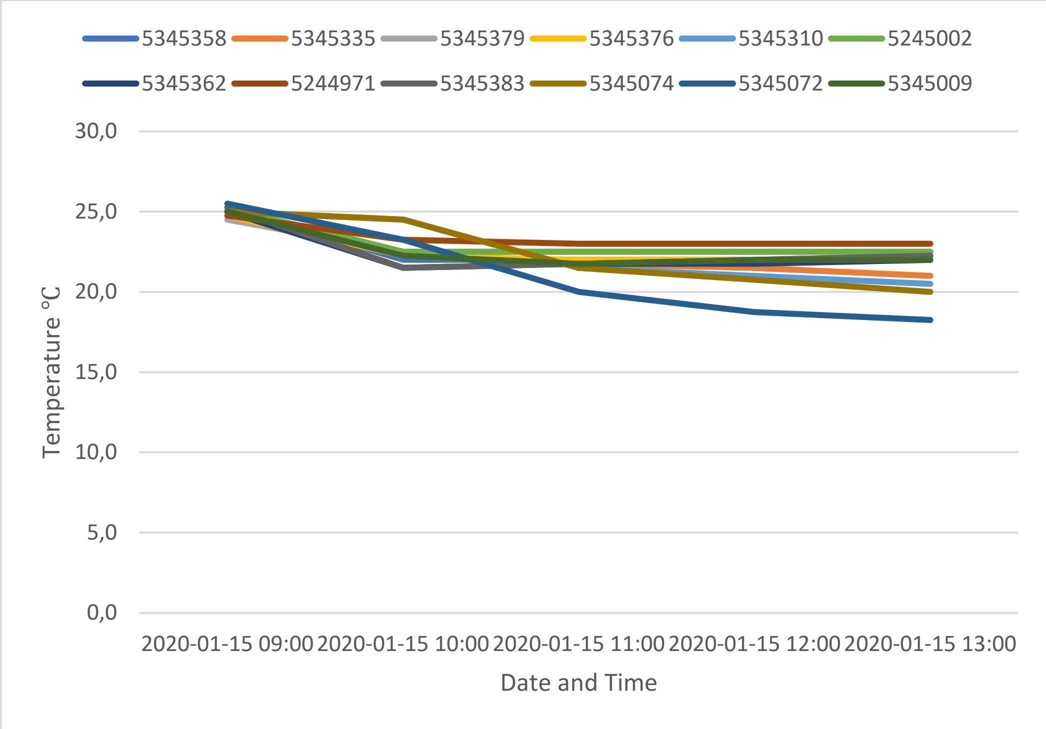


Figure 4.41: Packing stage for Concept A, Trial 3

All 12 devices indicated temperature breaks due to the temperature being warmer than 2 °C.

4.6.3.2 Concept A, Trial 3: Transfer stage

On 15 January 2020 at 14:40, the pallets were loaded into a refrigerated truck directly from the holding room with the use of an airlocked loading bay. The refrigerated unit of the truck was set at 18 °C.

For Concept A, Trial 3, the transfer stage from Packhouse A to Cold Treatment Facility A took four hours, including the loading and offloading processes.

Figure 4.42 illustrates the temperature data of the transfer stage.

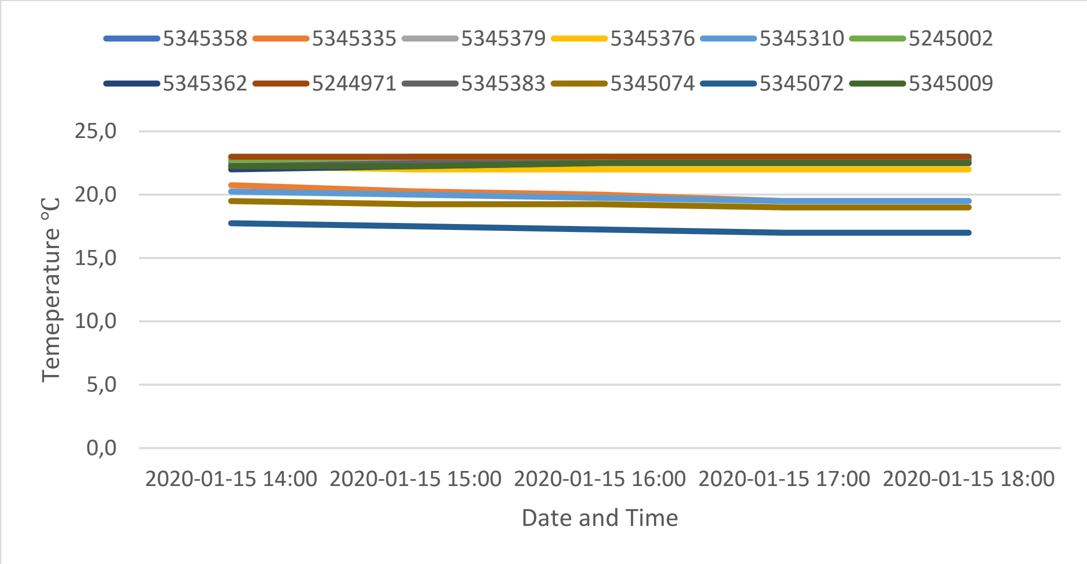


Figure 4.42: Transfer stage for Concept A, Trial 3

All 12 devices indicated temperature breaks due to the temperature being warmer than 2 °C during this stage.

4.6.3.3 Concept A, Trial 3: Forced-air cooling stage

Pallets were placed directly in the forced-air cooling tunnel and remained in the tunnel until the loading of the container took place as per Trial 3 of Concept A. Pallets of Trial 3 were in the forced-air cooling tunnel for 120 hours before the container loaded.

Figure 4.43 illustrates the temperature data of the first 48 hours of forced-air cooling as the first 48 hours are seen as best practice to get fruit to under -0.5 °C. Cold Treatment Facility A used the step-down cooling process. This method delays the practice to get the fruit to under -0.5 °C in 48 hours.

Figure 4.44 illustrates the temperature data of the 96 hours from when the forced-air cooling stage started to when the Steri stage starts.

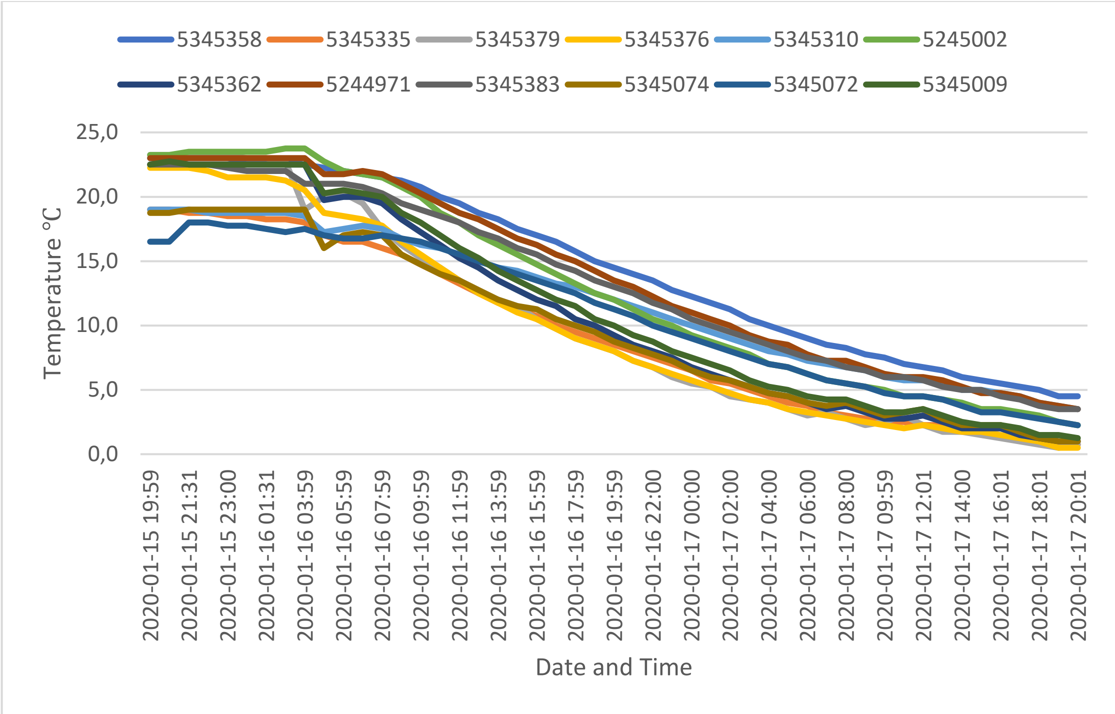


Figure 4.43: First 48 hours of the force-cooling stage for Concept A, Trial 3

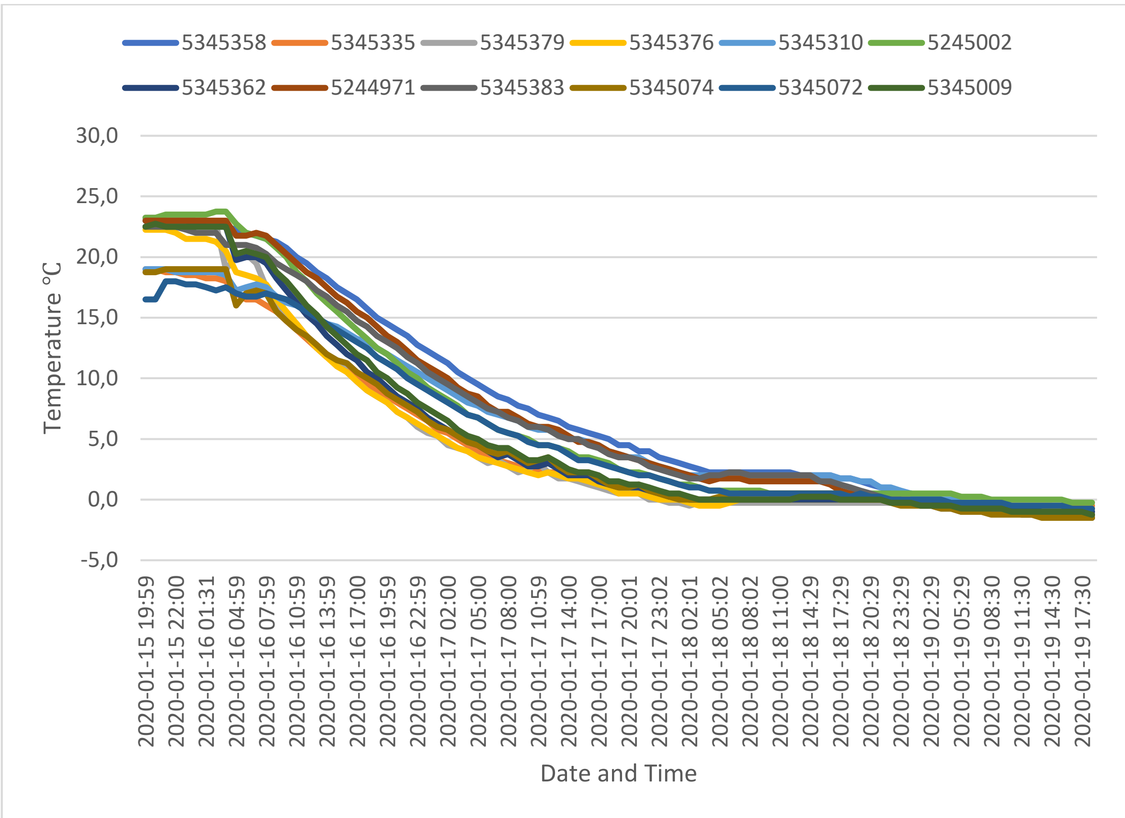


Figure 4.44: Forced-air cooling stage for Concept A, Trial 3

All 12 devices indicated temperature breaks for 52 hours, until the fruit pulp temperature of the average devices went below 2 °C. The reasons for the delay in getting the fruit to under 2 °C include the step-down cooling method, phytosanitary sample cartons being placed back onto the pallets, temperature monitors opening the tunnel to take physical temperature measurements and defrosting of cooling equipment. Two devices indicated temperature breaks of temperatures measuring -1.5 °C during the final two hours of the force cooling stage.

The average temperature data of the force cooling stage of the 12 devices are illustrated in Figure 4.45.

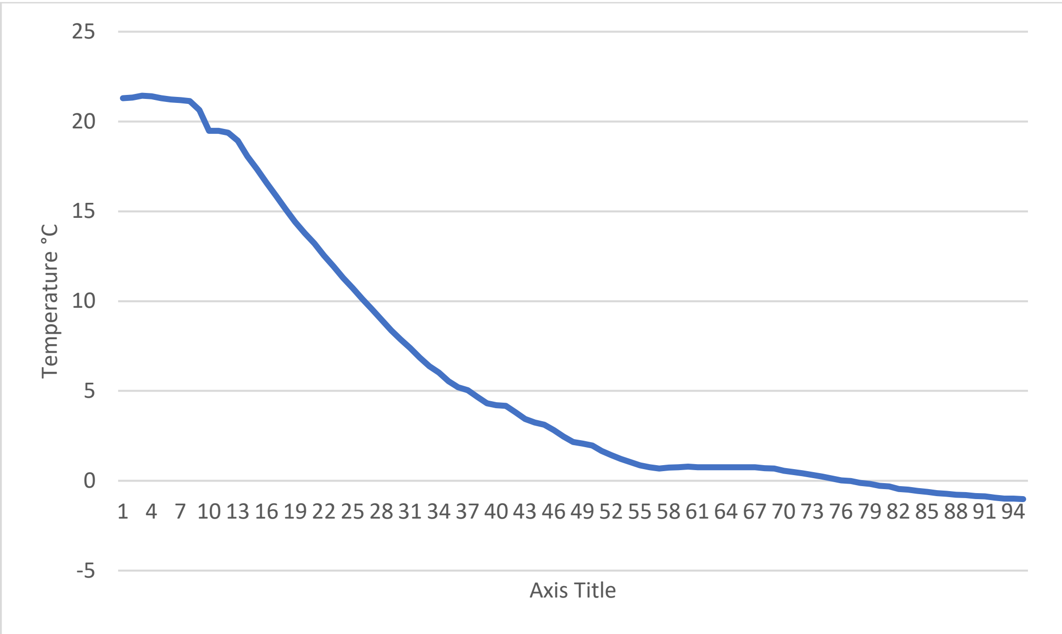


Figure 4.45: Average temperatures for the forced-air cooling stage Concept A, Trial 3

4.6.3.4 Concept A, Trial 3: Steri stage

The pallets were loaded for China. The researcher used the last 24-hour temperature data before the loading stage started, as the Steri stage.

Figure 4.46 indicates this temperature data.

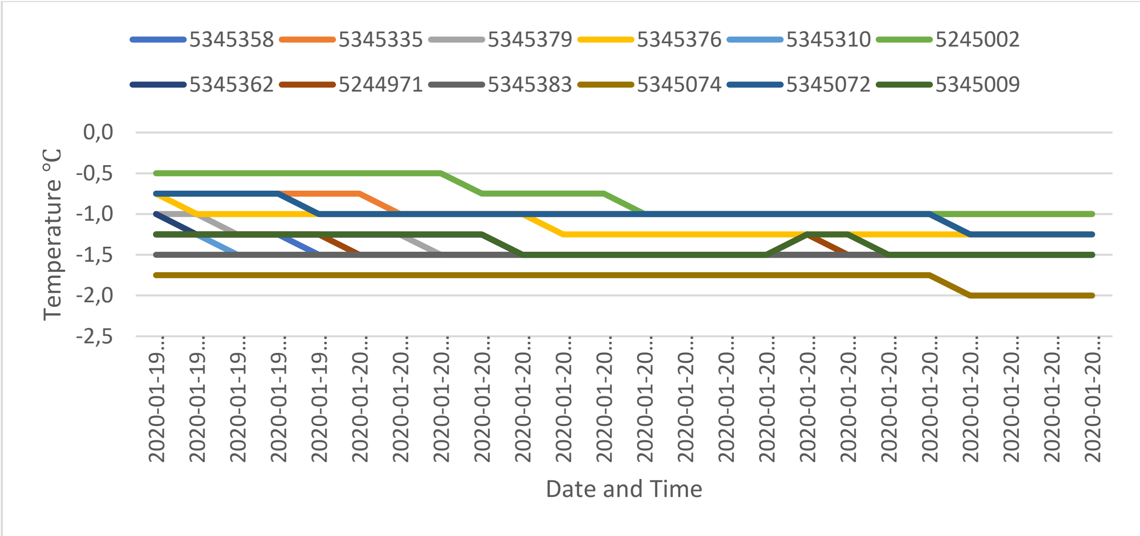


Figure 4.46: Steri stage for Concept A, Trial 3

Eight devices indicated temperature breaks, with temperature readings measuring -1.5 °C and colder.

Figure 4.47 illustrates the last six hours of the Steri stage where the pulp temperature must be between -0.5 °C and -1.2 °C.

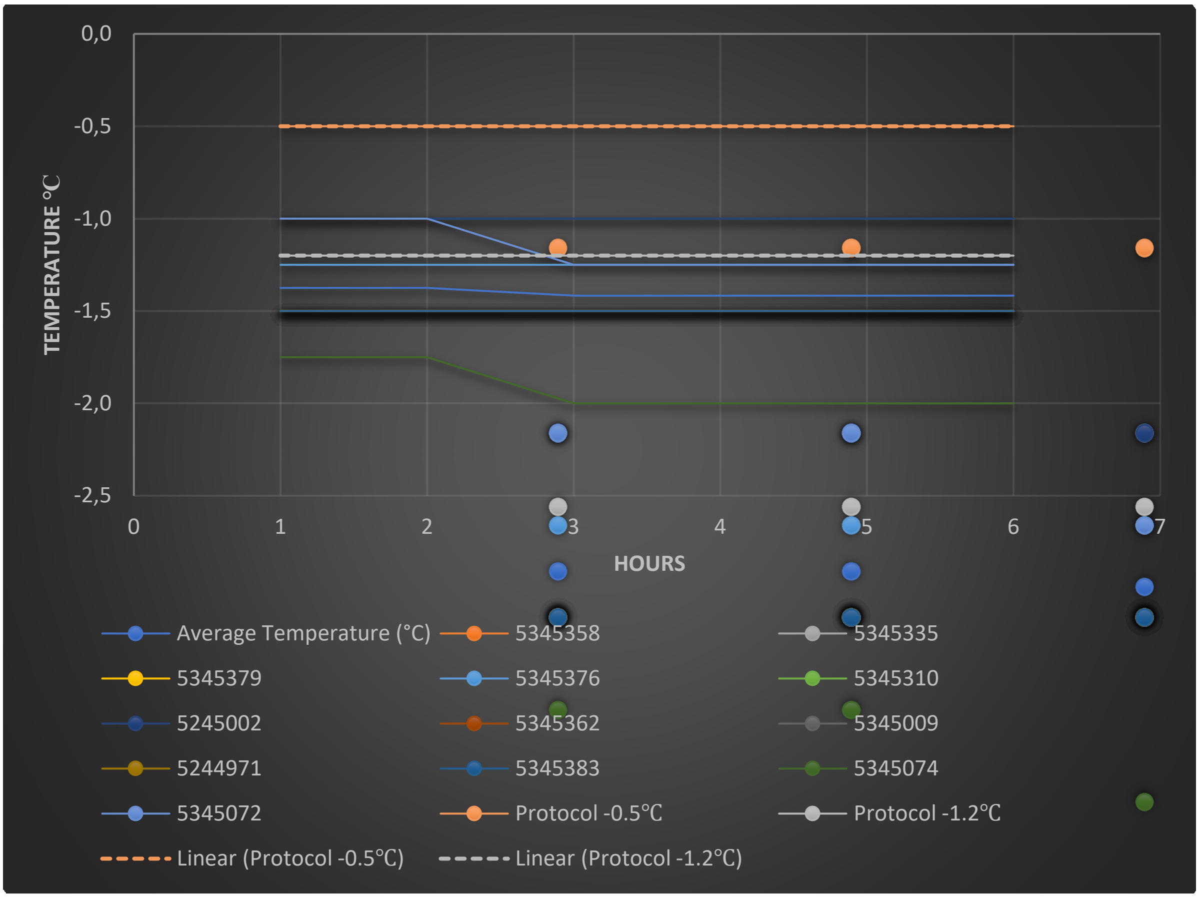


Figure 4.47: Last six hours of the Steri stage for Concept A, Trial 3

Nine of the 12 devices were out of protocol, being colder than -1.2 °C. The PPECB allows the setpoint of a room to be set to -1.5 °C to reach a pulp temperature of -1.2 °C. With the setpoint of a room set at -1.5 °C, the supply air of the tunnel deviates approximately between -2 °C and -1 °C due to the valves of the evaporator opening and closing to reach the desired temperature of -1.5 °C as per the setpoint. In Trial 3, the pallets were under forced-air cooling for 120 hours, thoroughly cooling the fruit and the fruit started to reach the temperature of the supply air.

Six fruit pulp sensors were used to supply the PPECB with a temperature printout of the last 24 hours before the fruit could be loaded to China. The researcher used the same pulp sensor data to add additional data to the Steri stage of Concept A, Trial 3, which is illustrated in Figure 4.48.

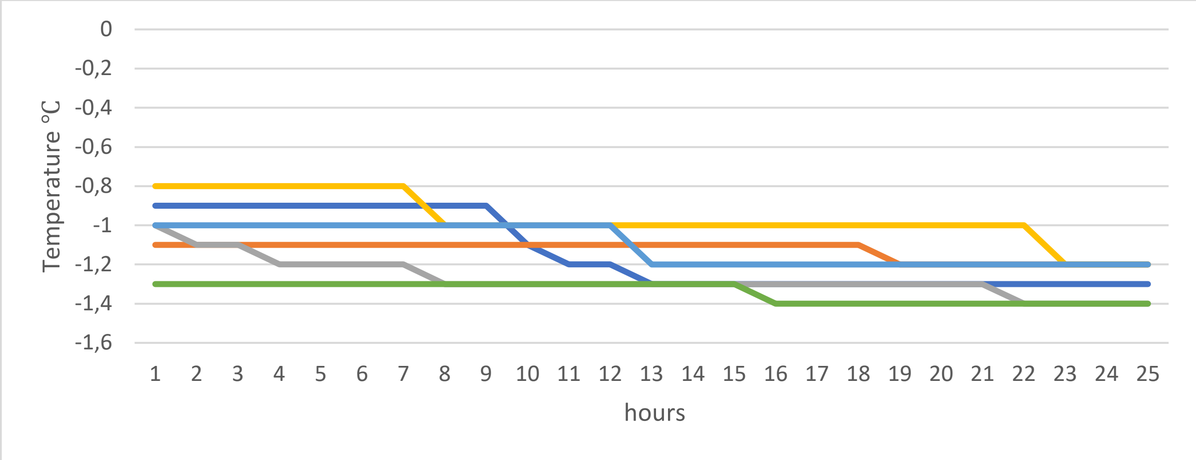


Figure 4.48: Pulp sensors used in the Steri stage for Concept A, Trial 3

No temperature breaks or spikes were identified in the six fruit pulp sensors supplied to the PPECB.

Figure 4.49 identifies the similarity between the averages of the temperature data measured with the devices and pulp sensors of Concept A, Trial 3.

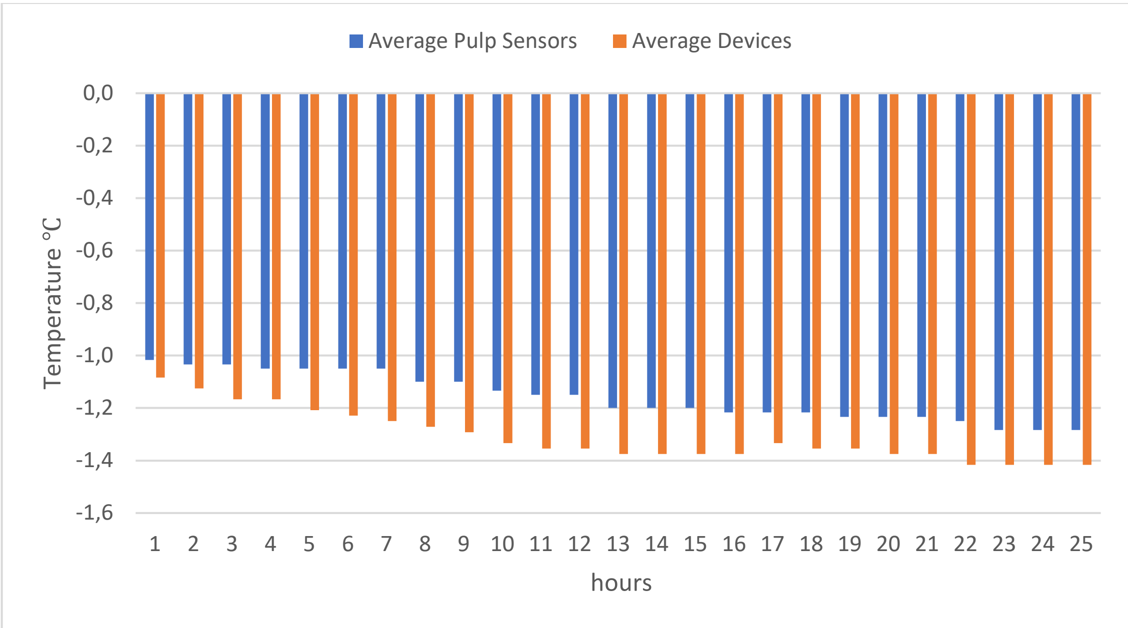


Figure 4.49: Average pulp sensors and devices of Concept A, Trial 3

4.6.3.5 Concept A, Trial 3: Loading stage

The loading process started at 19:47 and finished at 20:20 on 20 January 2020. Pallets were loaded into container number SZLU9355827. Eight devices indicated temperature breaks by measuring temperatures of -1.5 °C and colder.

Table 4.5 illustrates the temperature data for the loading stage.

Table 4.5: Temperature data for the loading process of Concept A, Trial 3

Date and Hours	Average Temperature (°C)	5345358	5345335	5345379	5345376	5345310	5245002	5345362	5244971	5345383	5345074	5345072	5345009
2020-01-20 19:30	-1.4	-1.5	-1.0	-1.5	-1.3	-1.5	-1.0	-1.5	-1.5	-1.5	-2.0	-1.3	-1.5
2020-01-20 20:30	-1.4	-1.5	-1.0	-1.5	-1.3	-1.5	-1.0	-1.5	-1.5	-1.5	-2.0	-1.3	-1.5

4.6.3.6 Concept A, Trial 3: Stacking and shipping stage

The container was transported from Cold Treatment Facility A to the stack in the Port of Ngqura. The container arrived at the stack on 21 January 2020 and was monitored in the stack for three days until the container was loaded onto the Vessel on 24 January 2020.

On 14 February 2020, the container was discharged in the Port of Hong Kong and was cleared by customs on 19 February 2020. The container arrived at Guangzhou's Jiangnan market in China on 19 February 2020. All data were retrieved up to 22 February 2020 when the fruit left the Jiangnan Market for the different retailers.

Figure 4.50 depicts the temperature data from when the container left Cold Treatment Facility A to when the pallets left the Jiangnan Market.

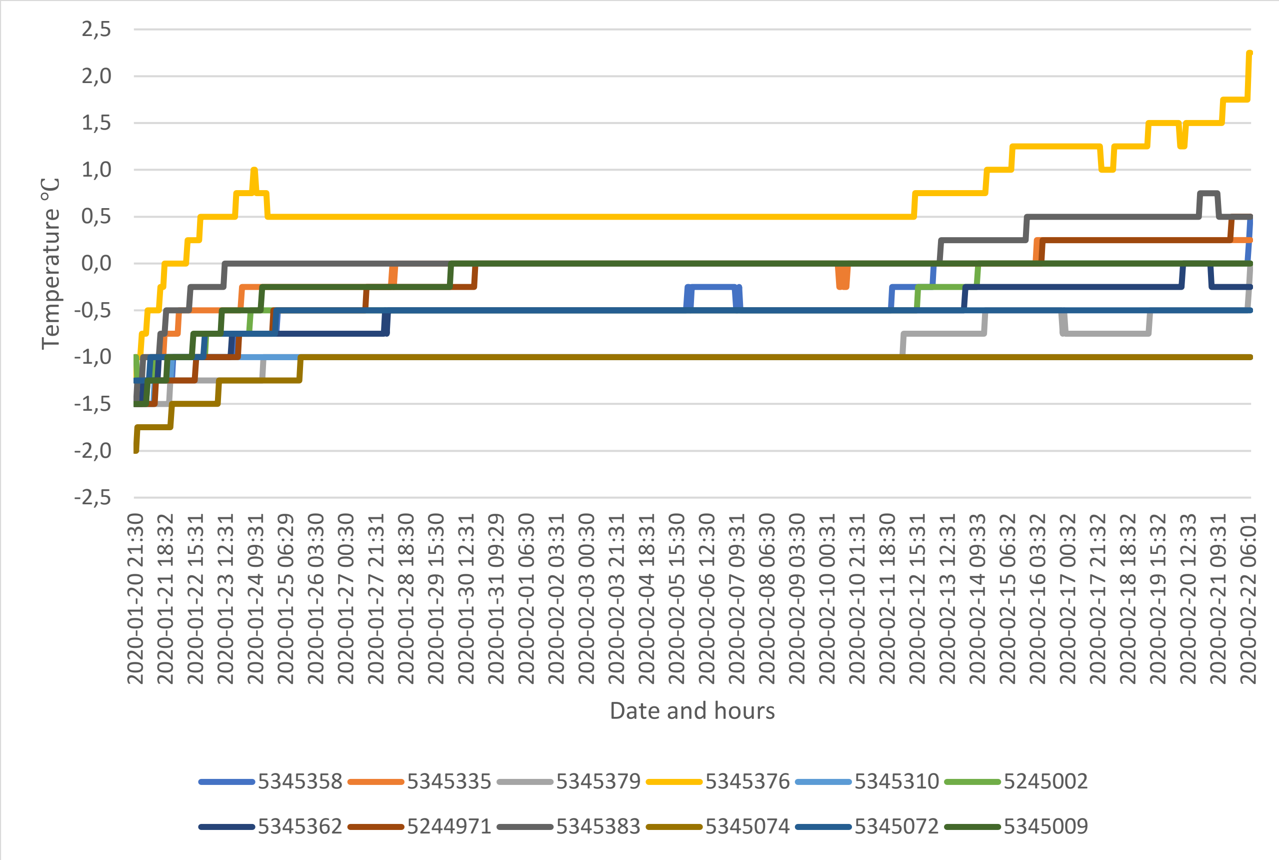


Figure 4.50: Temperature data from when container left Cold Treatment Facility A to pallets being loaded to retailers in China, Concept A, Trial 3.

The container setpoint is set at -1 °C. Grapes must be under cold treatment for 20 days after the container has been loaded for China. Day 20 was 9 February 2020 at 21:00 for Concept A, Trial 3.

Eight temperature breaks were identified in the start of the shipping stage by measuring temperatures below -1.5 °C, but a clear indication of pulp temperature increase can be seen in Figure 4.50. During the 20 cold treatment days, four devices went out of protocol with temperatures being warmer than -0.5 °C. The increase started in the stack at Coega and stabilised during the voyage on the vessel. The increase in temperature did not affect the cold treatment protocol and the 20 days were passed without any problems.

On 14 February 2020, the container was discharged in Hong Kong and the setpoint of the container was amended to -0.5 °C, causing a slight increase in the pulp temperature.

On 19 February 2020, the pallets were offloaded at the Jiangnan Market, causing an increase in temperature.

The researcher used Sensitech TempTale GEO number GKJ11008K1 to measure the air temperature at the door of the container. TempTale GKJ11008K1 was inserted into a carton of pallet ID 460091601516358407 facing the door of the container.

Figure 4.51 indicates the ambient air temperature measured.

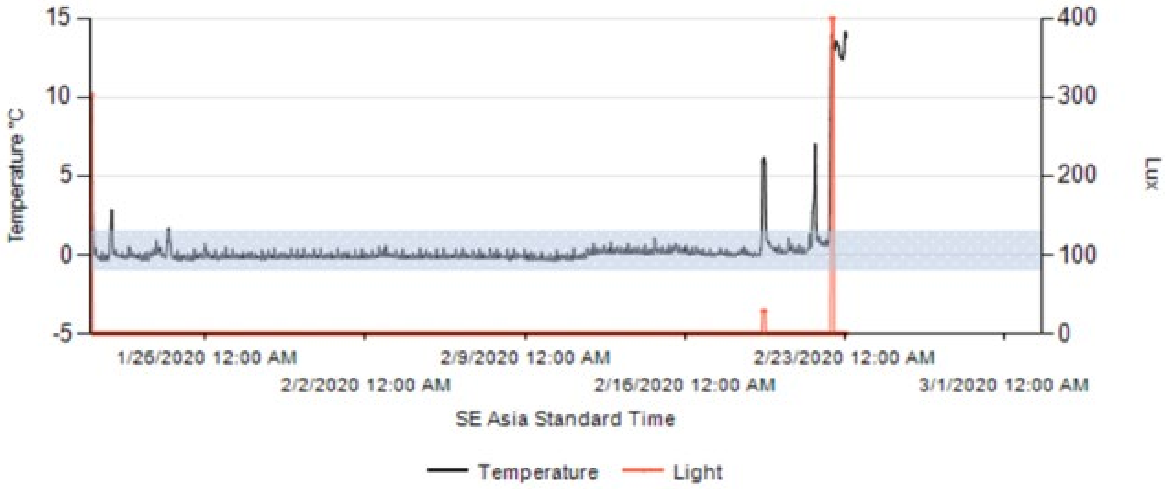


Figure 4.51: Ambient air temperature measured during Concept A, Trial 3

No temperature breaks were identified. A temperature spike did occur in the stack at the Port of Ngqura and during loading onto the vessel. The spike in the stack rose to a temperature of 2.8 °C.

4.6.4 Averages of Concept A

The averages of each trial supply a holistic view of Concept A. Figure 4.52 illustrates the average temperature data of all three trials of Concept A.

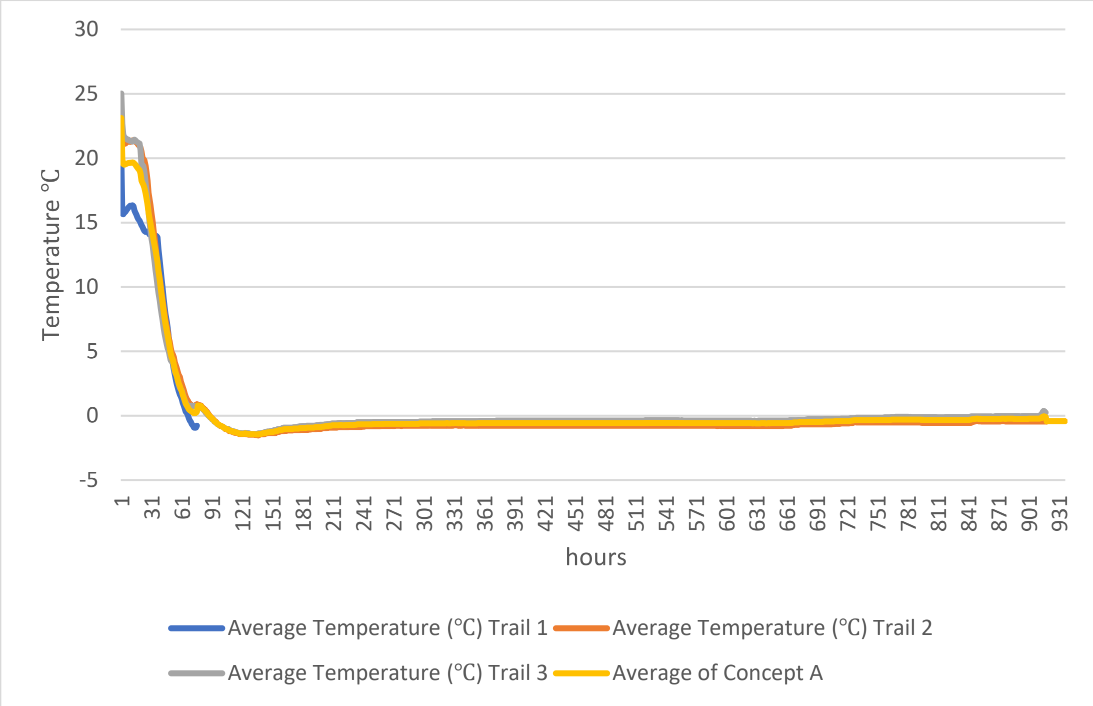


Figure 4.52: Temperature averages of Concept A

4.6.4.1 Averages of Concept A: Packing and transfer stage

The average time it took from when the grapes were being packed to being placed under forced-air cooling was 10 hours. The current best practice is to place the packed grapes in forced-air cooling within six hours after packing. Figure 4.53 illustrates the temperature averages from the grapes being packed to being placed under forced-air cooling.

The shape of the line diagram is similar for each trial. Trial 1 was done on a day that was cooler than Trials 2 and 3.

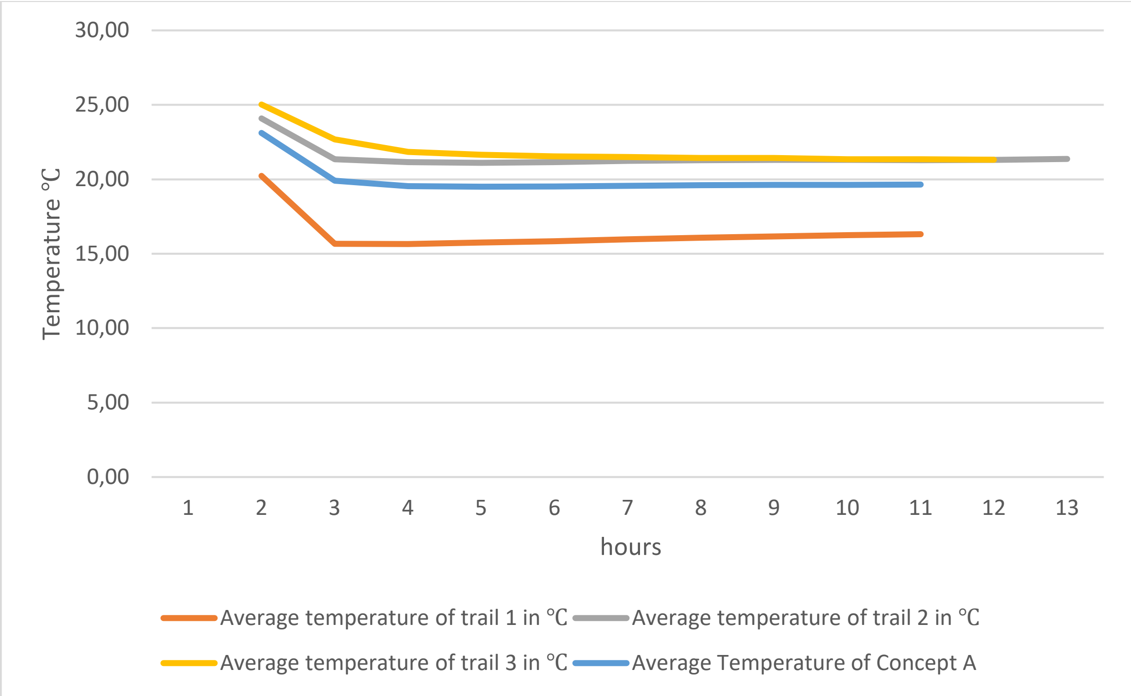


Figure 4.53: Temperature averages for Concept A

4.6.4.2 Averages of Concept A: Forced-air cooling stage

Cold Treatment Facility A used the step-down cooling process in all three trials.

The current best practice is to get fruit to under 10 °C within 12 hours and below -0.5 °C within 48 hours. The researcher used the average temperature data of all three trials to determine the time for Concept A's pulp temperature to reach 10 °C and -0.5 °C respectively.

Figure 4.54 indicates the number of hours it took to reach a pulp temperature of 10 °C during the forced-air cooling stage for Concept A and Figure 4.55 shows the number of hours it took for the pulp temperature to reach -0.5 °C.

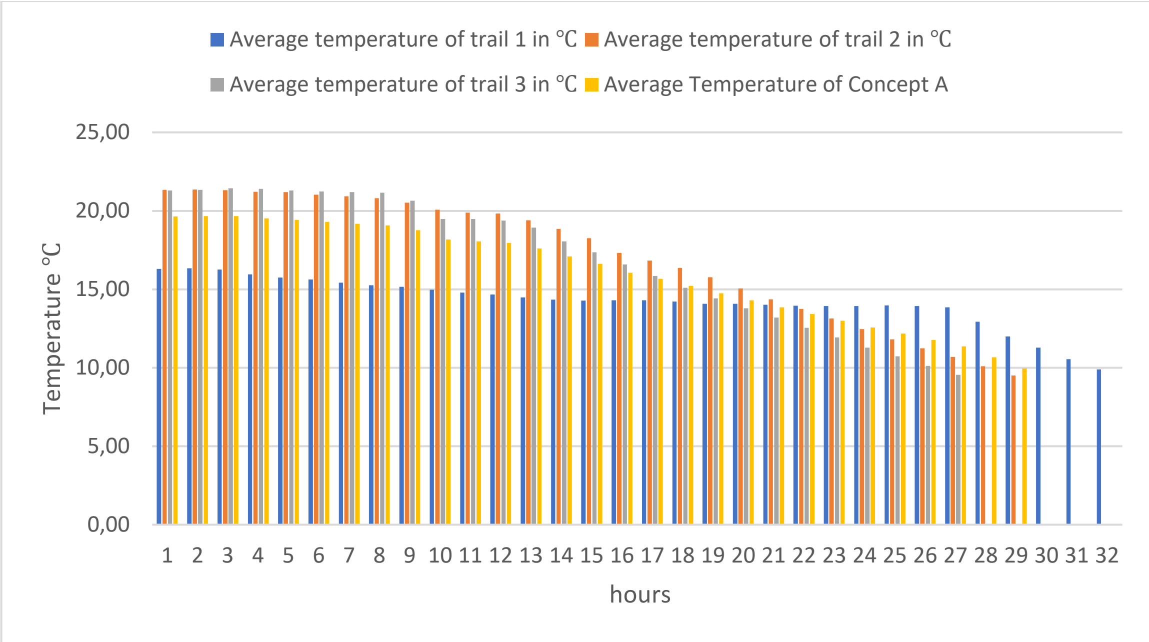


Figure 4.54: Force-cooling stage until 10 °C, Concept A

The average time it took the pulp temperature to reach 10 °C was 29 hours, 17 hours longer than the current best practice.

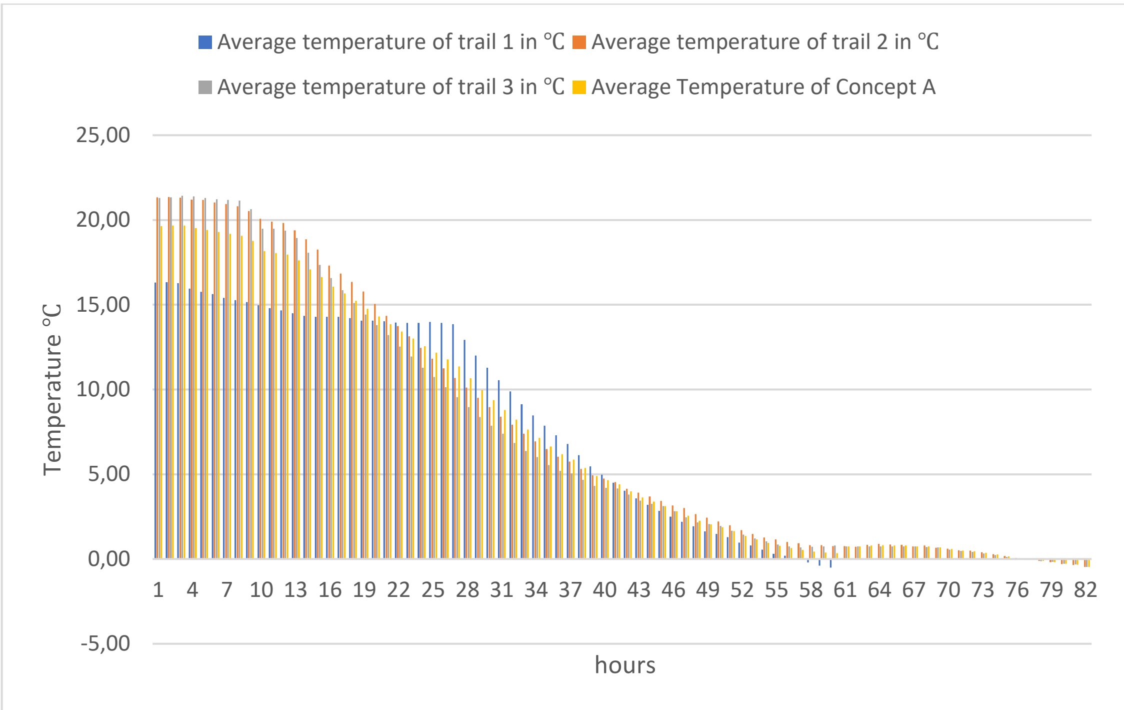


Figure 4.55: Force-cooling stage until -0.5 °C, Concept A

The average number of hours it took for the pulp temperature to reach -0.5 °C in Concept A was 75 hours, which is 27 hours longer than the advised best practice.

There are a number of reasons that could have caused Cold Treatment Facility A not to reach the desired best practice of cooling fruit to 10 °C in 12 hours and -0.5 °C in 48 hours.

The first reason is the step-down cooling process used in the forced-air cooling method. The second reason is that Cold Treatment Facility A has 34 tunnels, 12 of which can take 64 pallets and 22 can take 88 pallets. Due to condensation risks and cost-saving methods, forced-air cooling in the tunnels only starts when the tunnels are 50% filled. This causes delays, but can be overcome by greater volume. The third reason is negligence, such as the tunnels not being sealed correctly, tunnels not closed on time, tunnels opened too frequently, defrosting of rooms not done regularly and the incorrect stacking of pallets in the tunnel. Finally, it could be due to mechanical errors, for example, fans not rotating, ammonia not reaching the evaporators, tunnel doors not closing correctly and other mechanical malfunctions that could cause delays in the cooling process.

4.6.4.3 Averages of Concept A: Steri stage

All trials conducted for Concept A were for China-bound, therefore, the Steri stage can be seen as the last 24 hours before the grapes were loaded into the specific containers.

Figure 4.56 illustrates the averages per trial of the devices and the tunnel probe sensors used to determine the total average of the Steri stage for Concept A.

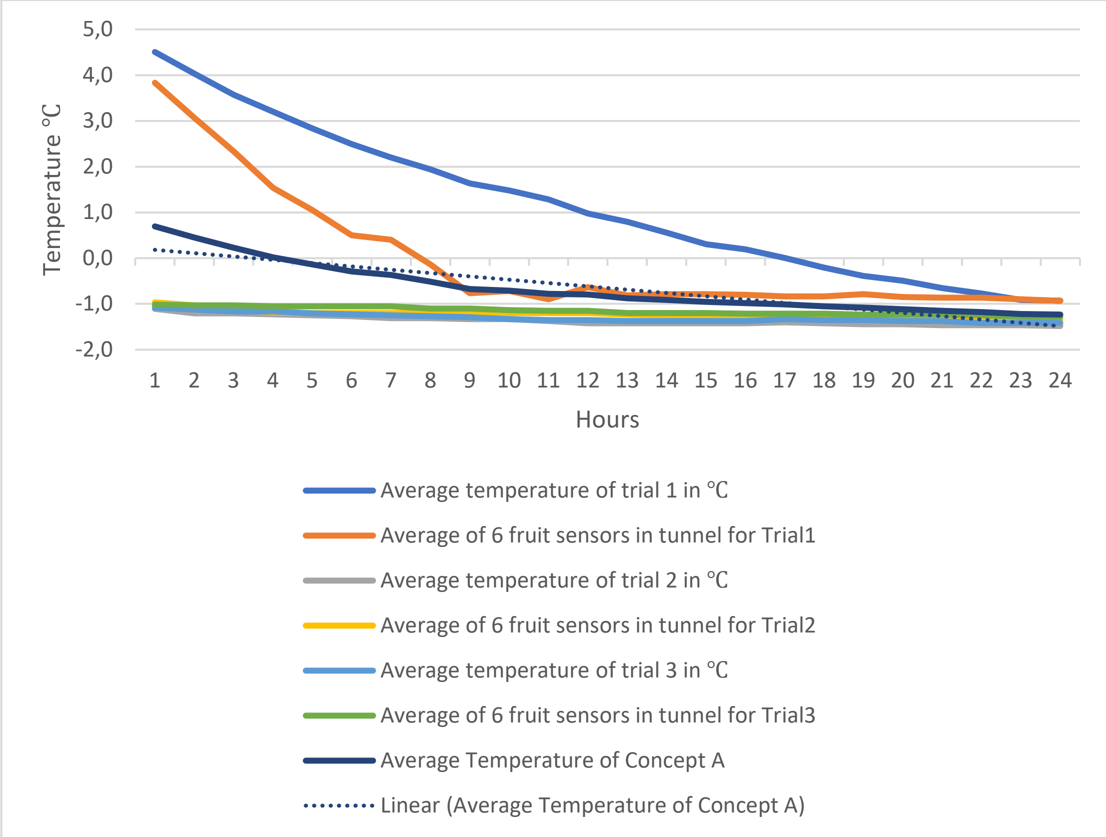


Figure 4.56: Temperature averages of the Steri stage, Concept A

Trial 1 was warmer than the other two trials, but three days after packing, Trial 1 was loaded to China. The line from of the final average data from Concept A is a perfect illustration of a Steri stage.

4.6.4.4 Averages of Concept A: Loading and shipping stage

Unfortunately, no temperature data for the shipping stage were obtained for Trial 1.

The temperature averages for Concept A measured from loading to arriving at the Jiangnan Market are illustrated in Figure 4.57. All three containers were loaded for Exporter A.

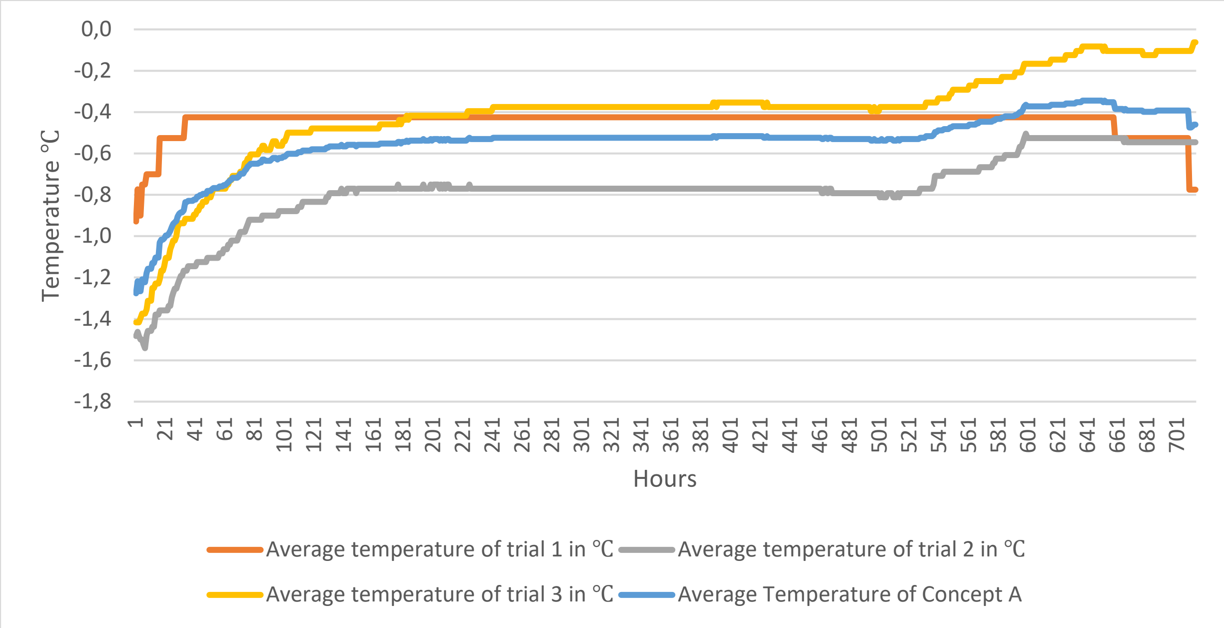


Figure 4.57: Temperature averages for the loading and shipping stage of Concept A

4.7 Concept B

This concept is the current method being used in the industry, where grapes from the Hex River production area are sent to Cold Storage Facility A. The grapes are force-cooled and transported to the registered cold treatment facilities after the forced-air cooling stage.

Cold Storage Facility A is located in the Hex River production area.

There are only five cold treatment facilities registered to handle all special market shipments. Four cold treatment facilities are located in Cape Town and the fifth is in Paarl.

A total of 40 devices were used to conduct the research, spread over three trials.

4.7.1 Concept B, Trial 1

Trial 1 was conducted on pallets destined for China. During the transfer stage from Cold Storage Facility A to Cold Treatment Facility B, Exporter B decided to divert the grapes to Rotterdam. Twelve devices were divided between three pallets. Pallet ID 560091600197953076 had four devices, namely 5244998, 5244957, 5244985 and 5345340. Pallet ID 560091600197953069 had four devices, namely 5244913, 5345380, 5345092 and 5345035. Pallet ID 560091600197953057 had four devices, namely 5345077, 5244970, 5345309 and 5245008.

The devices were inserted at 08:00 on 30 January 2020 at Packhouse A. The consignment containing pallet IDs 560091600197953076, 560091600197953057 and 560091600197953069 arrived at Cold Storage Facility A at 13:15 on 30 January 2020.

On 2 February 2020 at 01:14, the grapes were transported to Cold Treatment Facility B, arriving at 05:14. The fruit was loaded for Rotterdam on 3 February 2020 at 08:13.

Figure 4.58 illustrates the average temperature data of Trial 1 of Concept B. Figure 4.59 illustrates the temperature data of the 12 devices used in Trial 1 of Concept B.

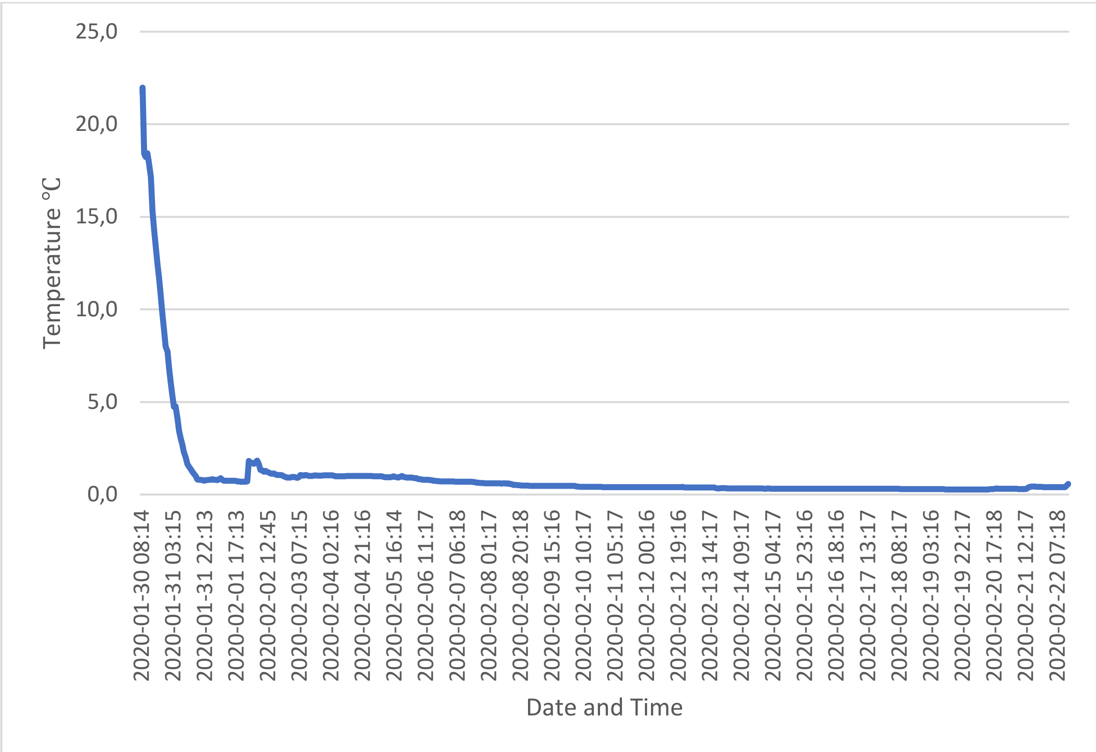


Figure 4.58: Average temperature data of Concept B, Trial 1

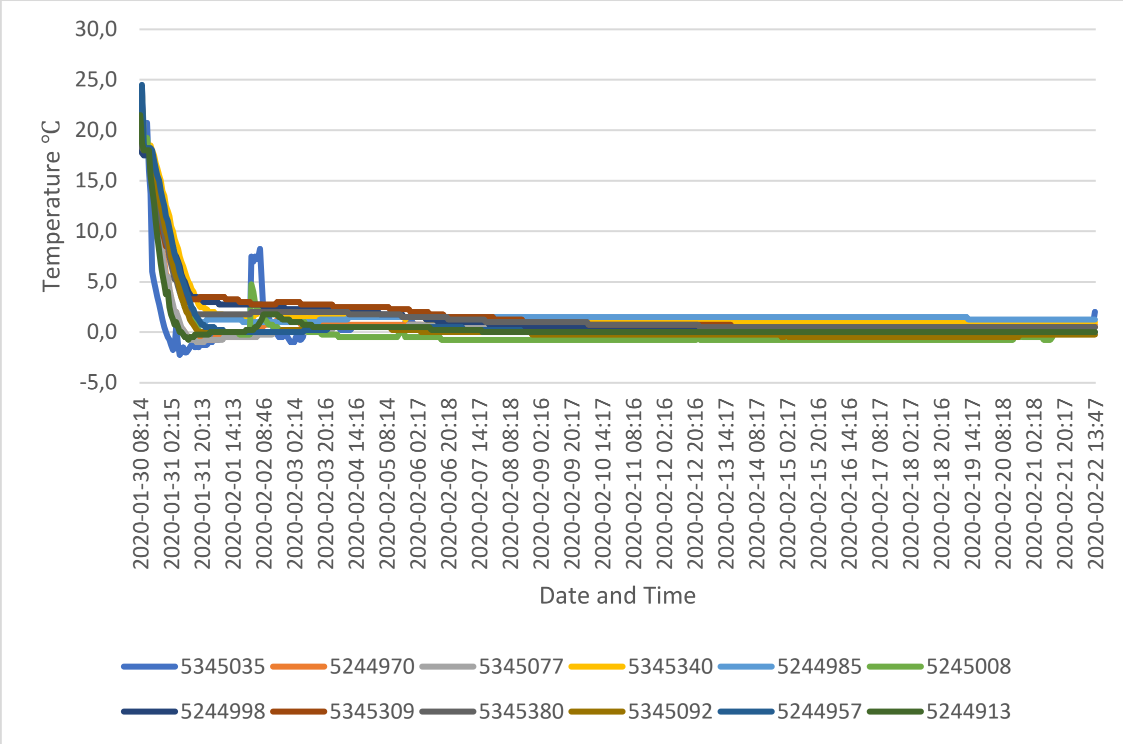


Figure 4.59: Temperature data for 12 devices used for Concept B, Trial 1

4.7.1.1 Concept B, Trial 1: Packing stage

IFG Seventeen (Sweet Joy) grapes were packed on 30 January 2020 at Packhouse A. The grapes were packed in B04I cartons, 180 cartons palletised per pallet. IFG Seventeen (Sweet Joy) is a black seedless grape variety with medium to large berry size (Good Fruit Guide, 2020:1).

The researcher inserted the devices at 08:14 while the pallets were palletised, whereafter the pallets were moved to a holding area that was set at 18 °C. Pallets were kept in the holding area until 11:15. The packing and holding stage took approximately three hours before pallets were loaded onto a small flatbed truck. Figure 4.60 illustrates the temperature data during the packing stage of Concept B, Trial 1.

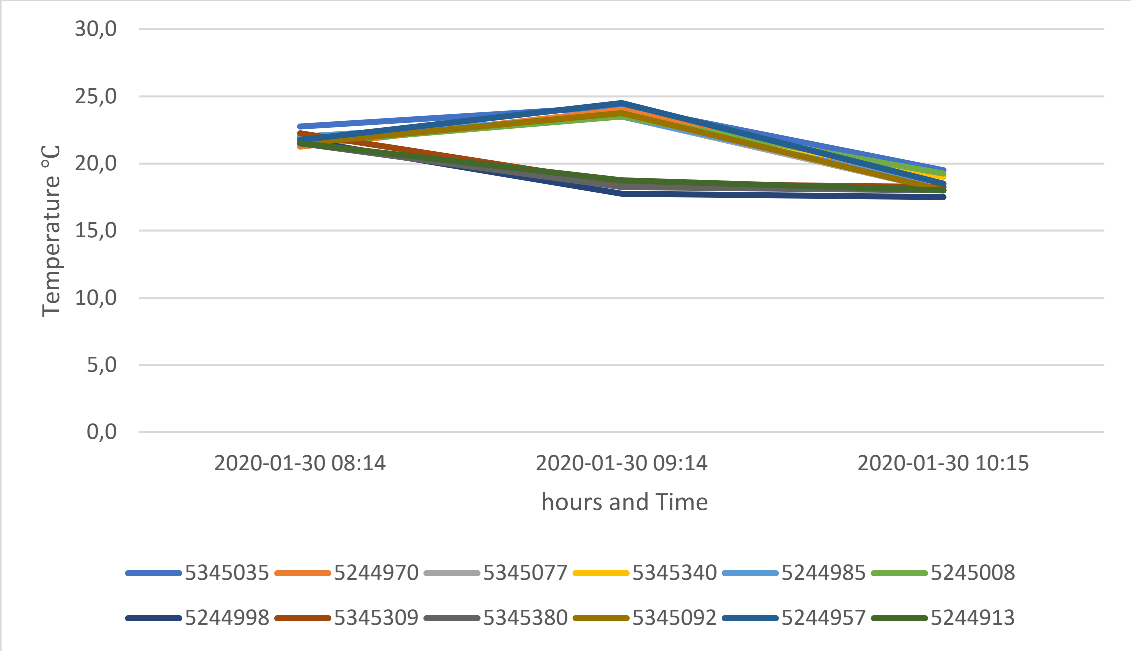


Figure 4.60: Packing stage temperature data for Concept B, Trial 1

All 12 devices indicated temperature breaks, due to the temperature being warmer than 2 °C.

4.7.1.2 Concept B, Trial 1: Transfer stage from Packhouse A to Cold Storage Facility A

On 30 January 2020 at 11:15, the pallets were loaded onto a small flatbed truck. The flatbed truck is open with no sails for isolation or refrigerated unit to keep the temperature consistent.

For Concept B, Trial 1, the transfer stage from Packhouse A to Cold Storage Facility A took one hour, including the loading and offloading processes.

Table 4.6 illustrates the temperature data of the transfer stage.

Table 4.6: Temperature data from Packhouse A to Cold Storage Facility A

Date and Time	5345035	5244970	5345077	5345340	5244985	5245008	5244998	5345309	5345380	5345092	5244957	5244913
2020-01-30 11:15	19.0	18.3	17.8	18.5	18.0	19.3	17.5	18.3	18.0	18.0	18.3	18.0
2020-01-30 12:15	20.8	18.5	18.0	18.5	18.0	19.3	17.8	18.3	18.0	18.0	18.3	18.0

All 12 devices indicated temperature breaks and five of these devices had a temperature increase due to the warmer outside temperature during the transfer stage.

4.7.1.3 Concept B, Trial 1: Forced-air cooling stage

Pallets were offloaded under a covered area and moved to a forced-air cooling tunnel. The process took one hour before the forced-air cooling process was started. Cold Storage Facility A does not use the step-down cooling procedure. Cold Storage Facility A sets the setpoint of the forced-air cooling room to -1.5 °C from the beginning of the forced-air cooling stage.

Pallets of Trial 1 were in the forced-air cooling tunnel for 48 hours. Thereafter, the pallets were moved to a holding room where the grapes were stored for 11 hours before they were loaded to Cold Treatment Facility B.

Figure 4.61 depicts the temperature data of the first 48 hours of forced-air cooling, as the first 48 hours is seen as best practice to get fruit to under -0.5 °C.

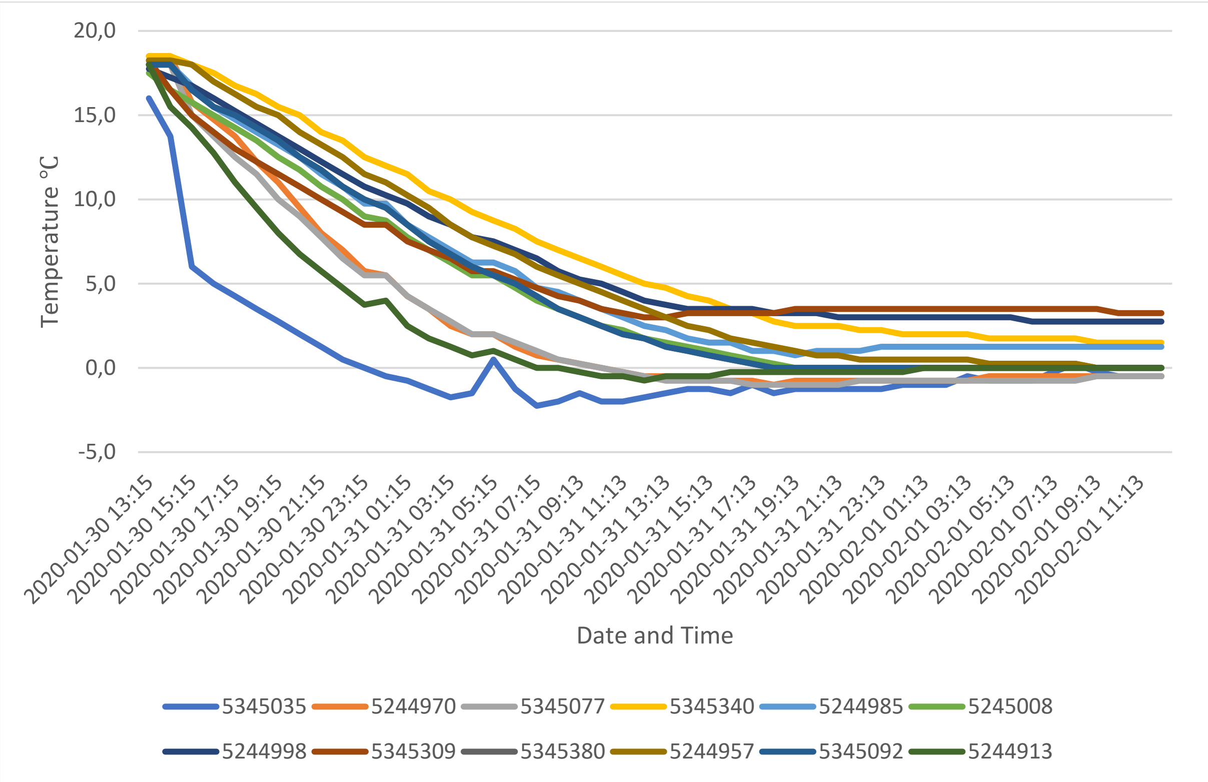


Figure 4.61: 48-hour forced-air cooling stage for Concept B, Trial 1

All 12 devices measured temperatures above 2 °C for the first 24 hours of the forced-air cooling stage, therefore, they are seen as temperature breaks. One temperature device measured temperatures of -2.3 °C indicating a temperature break. Nine of the 12 devices were under 10

°C in the first 12 hours of forced-air cooling and three of the devices were under -0.5 °C in the 48 hours of forced-air cooling.

Temperature fluctuations were identified. After the 48 hours of cooling, two devices indicated temperature breaks by being warmer that 2 °C. The temperature fluctuations are caused by the warm temperature of the pallets added into the forced-air cooling room. Cold Storage Facility A has big forced-air cooling rooms, with forced-air cooling tunnels built into the room. As soon as one tunnel is completed, the suction fans are switched on and the forced-air cooling stage starts. When this process is completed, pallets are placed in the second tunnel and so the process continues until the room is full. Pallets can be placed under forced-air cooling immediately, but the negative points are that the risk of condensation increases as temperature increases or fluctuates.

Figure 4.62 illustrates the temperature data of the 59 hours the pallets were stored and handled at Cold Storage Facility A.

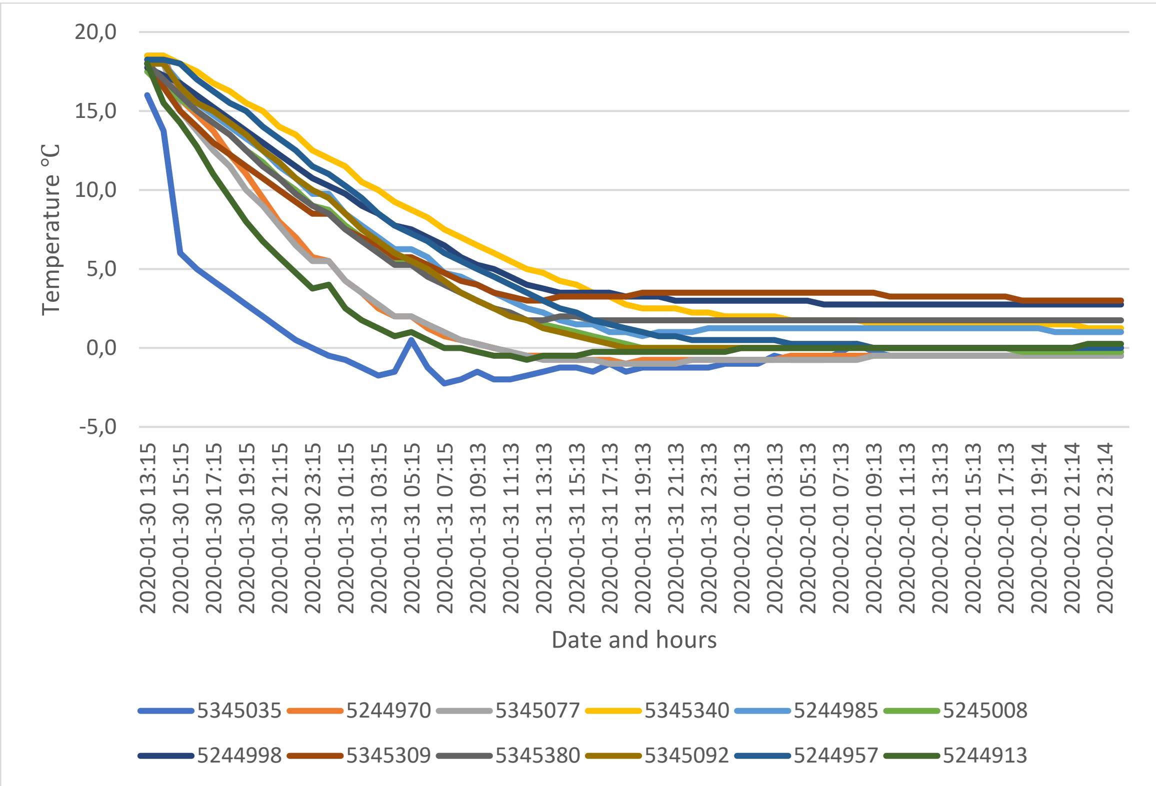


Figure 4.62: Cold storage facility temperature data for Concept B, Trial 2

All 12 devices indicated a temperature break. For the first section of the stage the temperatures were all warmer than 2 °C. As the fruit cooled down, one device went colder than -1.5 °C indicating a temperature break and two devices measured above 2 °C also indicating a temperature break. Figure 4.63 illustrates the average temperature data of the forced-air cooling stage at Cold Storage Facility A for Concept B, Trial 1.

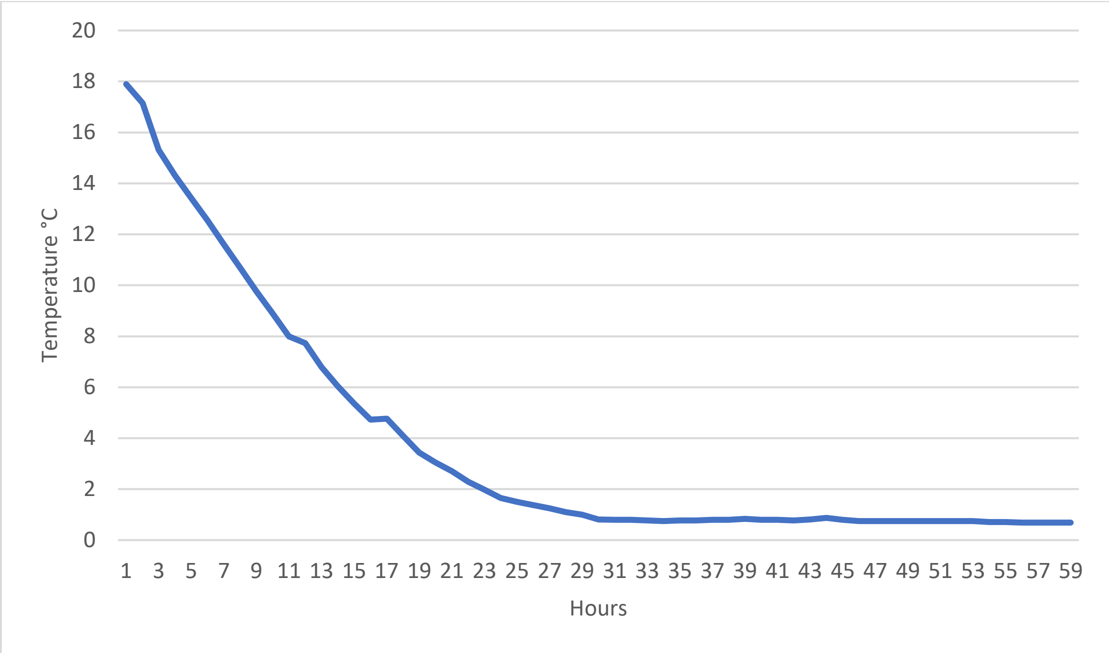


Figure 4.63: Average temperature from the forced-air cooling stage. Concept B, Trial 1

4.7.1.4 Concept B, Trial 1: Transfer stage from Cold Storage Facility A to Cold Treatment Facility B

Pallets were loaded on a super-link curtain trailer truck, more commonly known as a tautliner on 02 February 2020 at 00:30. Cold Storage Facility A prefers to load from midnight because of the night temperatures being cooler than during the day. It is a three-hour drive from Cold Storage Facility A to Cold Treatment Facility B. Taking into regard all the operational functions that need to take place, it took six hours before the fruit was standing in a holding room at Cold Treatment Facility B for Concept B, Trial 1.

Figure 4.64 illustrates the temperature data of the transfer stage from Cold Storage Facility A to Cold Treatment Facility B for Concept B, Trial 1.

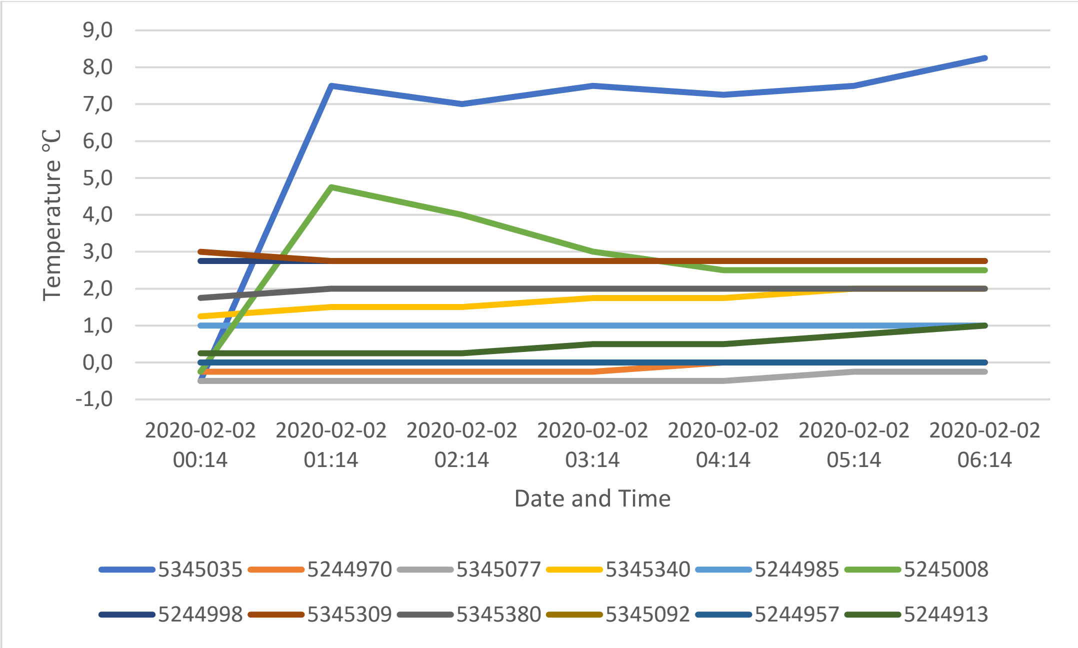


Figure 4.64: Temperature data from transfer stage from Cold Storage Facility A to Cold Treatment Facility B. Concept B, Trial 1

Temperature breaks were identified on six devices that were positioned in the outer layer of cartons on the pallets. Two devices were positioned in the outer layer of cartons on the pallets, 5245008 and 5345035. The temperature reading of device 5345035 increased from -0.5 °C to 7.5 °C. The temperature break lasted eight hours before the temperature decreased to below 2 °C.

The temperature reading of device 5245008 increased from -0.3 °C to 4.8 °C. The temperature break lasted eight hours before the temperature decreased to below 2 °C.

The temperature break occurred due to whole pallets not being at the correct temperature and the mode of transport was not able to regulate the temperature. The warmer air on the outside caused the pallet temperature to increase. Tautliner transport is not ideal for optimal cold chain management.

4.7.1.5 Concept B, Trial 1: Storage stage at the cold treatment facility

The normal practice is to place the pallets in a holding room while the samples are drawn and presented for phytosanitary inspection. After the inspection, the samples are placed back onto the relevant pallets. The phytosanitary-passed pallets are placed in Steri tunnels as per each market protocol.

Exporter B, the owner of the grapes, identified the Netherlands as the preferred market for these pallets. To be able to export to Europe, the pulp temperature of the fruit must be under 1.5 °C (Chetty, 2020:6). Six of the 12 devices were colder than 1.5 °C.

Figure 4.65 illustrates the temperature data of the holding stage at Cold Treatment Facility B, Concept B, Trial 1. Pallets were stored in the holding room that is set at -1 °C. Figure 4.66 illustrates the temperature data of the 25 hours the grapes were stored at Cold Treatment Facility B.

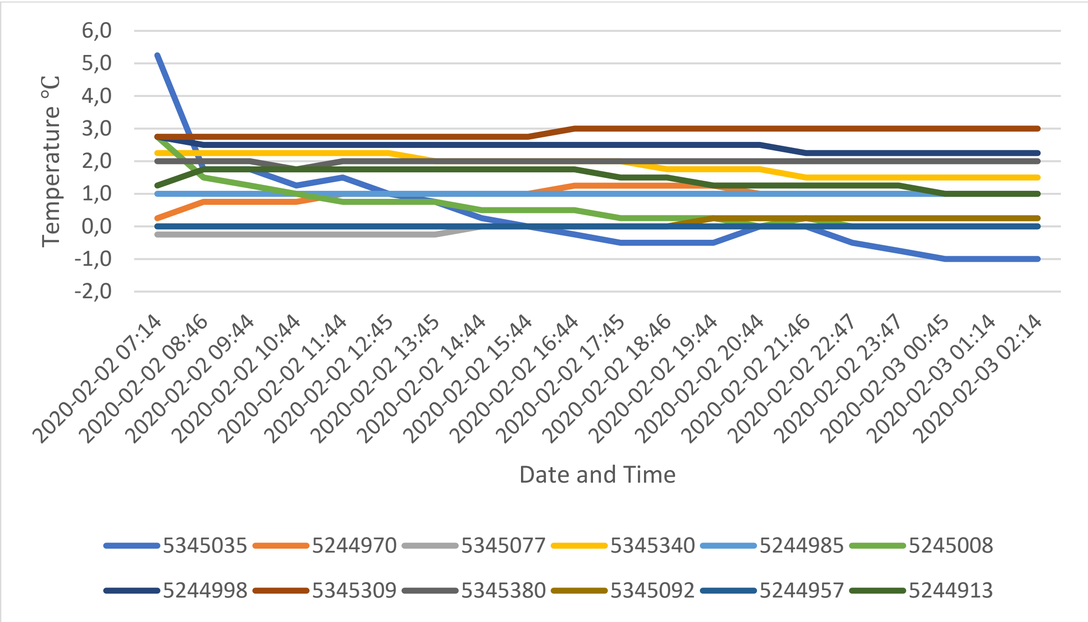


Figure 4.65: Temperature data of holding stage at Cold Treatment Facility B, Concept B, Trial 1

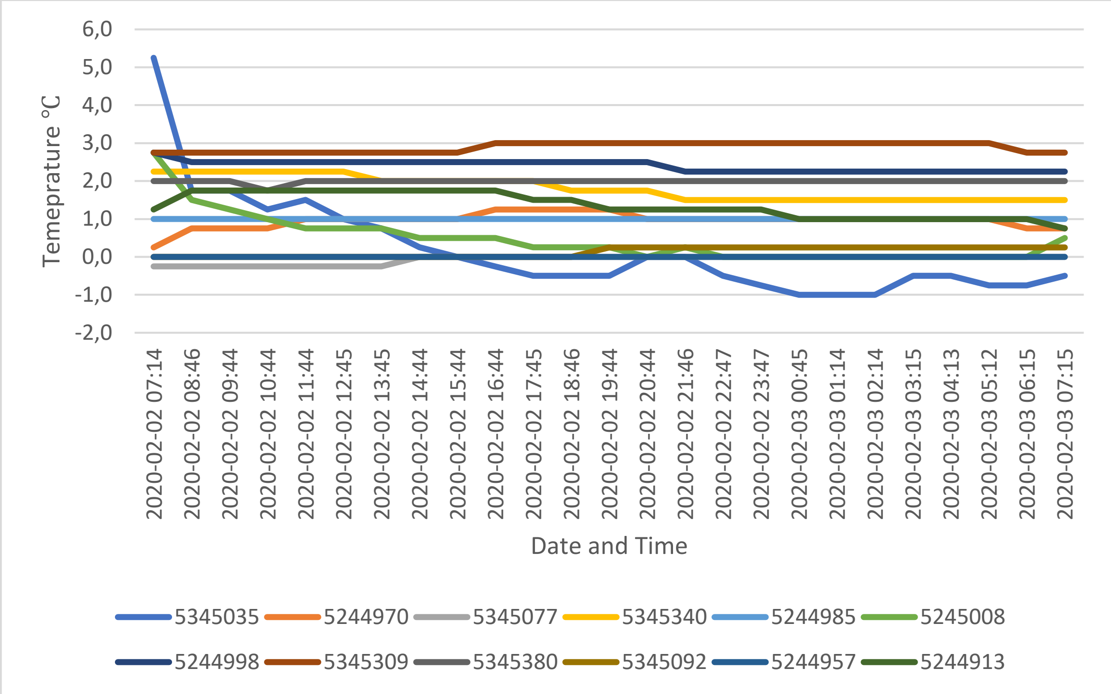


Figure 4.66: Temperature data of 25 hours the grapes were stored at Cold Treatment Facility B. Concept B, Trial 1

Five temperature breaks were identified during this stage, due to the fruit temperature being warmer than 2 °C. This stage was not the cause of the temperature break, but the temperature breaks could be avoided during this stage by additional forced- air cooling.

One temperature spike was identified and only nine devices measured under 1.5 °C, indicating that the pallets were not cooled through the pallet to reach the required temperature for exporting to Europe. The required temperature is between -1.2 °C and 1.5 °C.

The average temperature was under 1.5 °C and the PPECB allowed the pallets to be loaded into the container.

4.7.1.6 Concept B, Trial 1: Loading stage

The PPECB measured the temperature of four pallets and found that all four pallets were under 1.5 °C, allowing Cold Treatment Facility B to load the pallets.

Pallets were loaded on 03 February 2020 at 08:00 into container number TCLU1244191.

Table 4.7 illustrates the temperature data of the 12 devices during the loading stage.

Table 4.7: Temperature data of the 12 devices measured during the loading stage of Concept B, Trial 1

Date and Time	5345035	5244970	5345077	5345340	5244985	5245008	5244998	5345309	5345380	5345092	5244957	5244913
2020-02-03 07:15	-0.5	0.8	0.0	1.5	1.0	0.5	2.3	2.8	2.0	0.3	0.0	0.8
2020-02-03 08:13	0.3	0.8	0.0	1.5	1.0	1.0	2.3	2.8	2.0	0.3	0.3	0.8

Three devices had temperature breaks. Containers to Europe do not have to be fitted with a Genset unit if the loading point is within two hours from the port. Cold Treatment Facility B is within 30 minutes from the Port of Cape Town, and therefore, no Genset was fitted onto the trailer of the truck carrying container number TCLU1244191. For cold treatment markets, the cooling unit of the container is switched on to pre-cool the container prior to being loaded. For containers going to non-cold treatment markets, this is not mandatory. Container TCLU1244191 was not pre-cooled. Pallets were loaded into a warm container, increasing the risk for temperature increases and condensation on the fruit to occur.

4.7.1.7 Concept B, Trial 1: Stacking and shipping stage

Container number TCLU1244191 was transported from Cold Treatment Facility B to the container stack in the Port of Cape Town. The container arrived in Naaldwijk in South Holland on 22 February 2020. The entire process from loading to arriving at the cold storage facility in Naaldwijk took 19 days. Figure 4.67 illustrates the temperature data of the 19 days. Three temperature breaks were identified in the start of the stage by being 2 °C and warmer.

All the devices measured under 1.5 °C as the temperatures stabilised. The setpoint of the container was set at -0.5 °C.

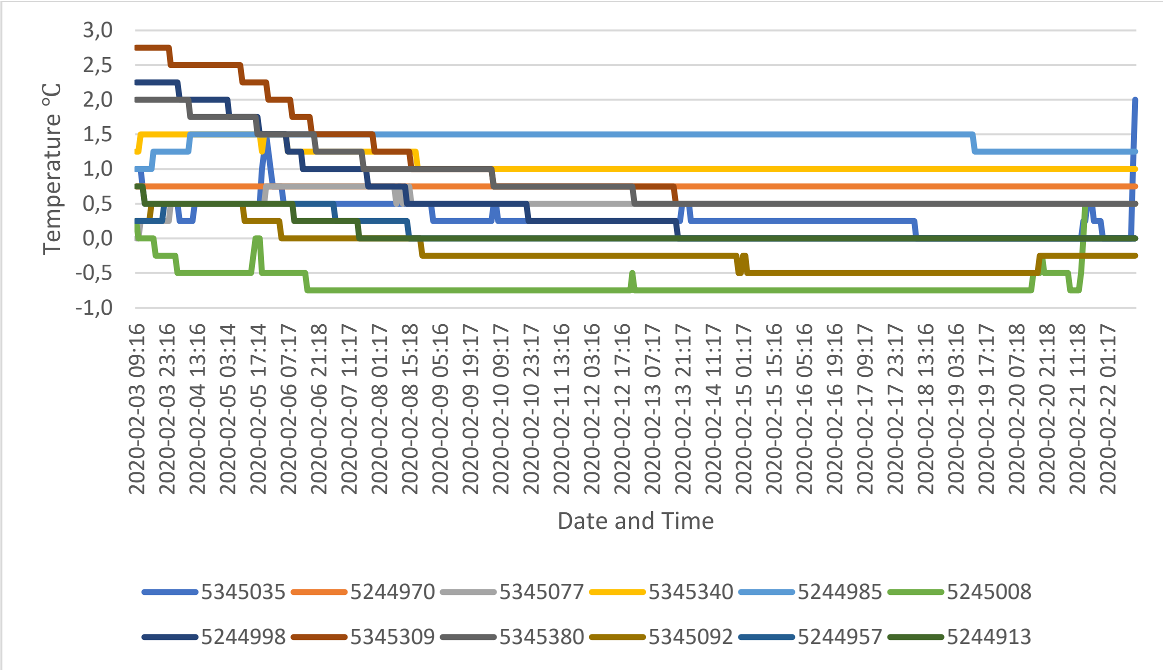


Figure 4.67: Temperature data from after loading to arrival at DC in the Netherlands. Concept B, Trial 1

4.7.2 Concept B, Trial 2

Due to the COVID-19 pandemic, the opportunities to gather research data for cold treatment markets were challenging for the researcher. Trial 2 of Concept B gathered data from the Berg River production area and not the Hex River production area. however, the concept was the same as the grapes were packed at Packhouse B, transported to Cold Storage Facility B and after the forced-air cooling stage, transported to Cold Treatment Facility B.

Eight devices were used for this trial and grapes were packed for Vietnam. The eight devices were divided between pallets. Device numbers 5345000, 5244943, 5244956 and 5345088 were inserted into pallet ID 360095142001912104. Device numbers 5345299, 5345090, 5244924 and 5244922 were inserted into pallet ID 360095142001912036. The average temperature data for Concept B, Trial 2 are illustrated in Figure 4.68 and the eight device temperature data are illustrated in Figure 4.69.

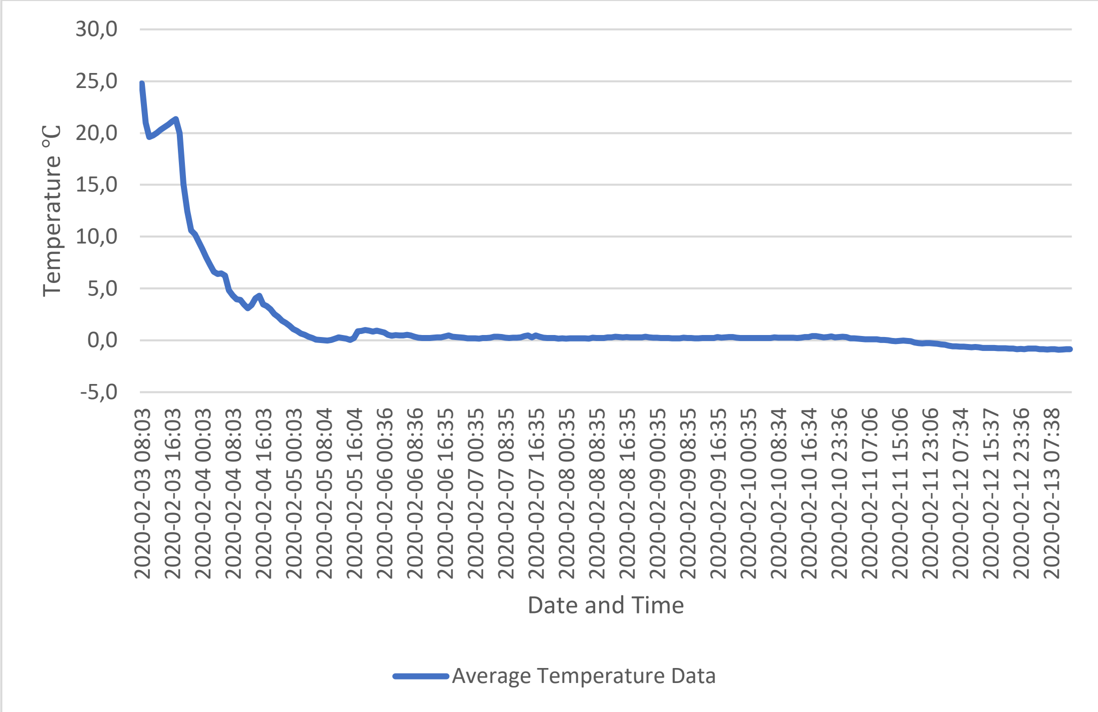


Figure 4.68: Average temperature data of Concept B, Trial 2

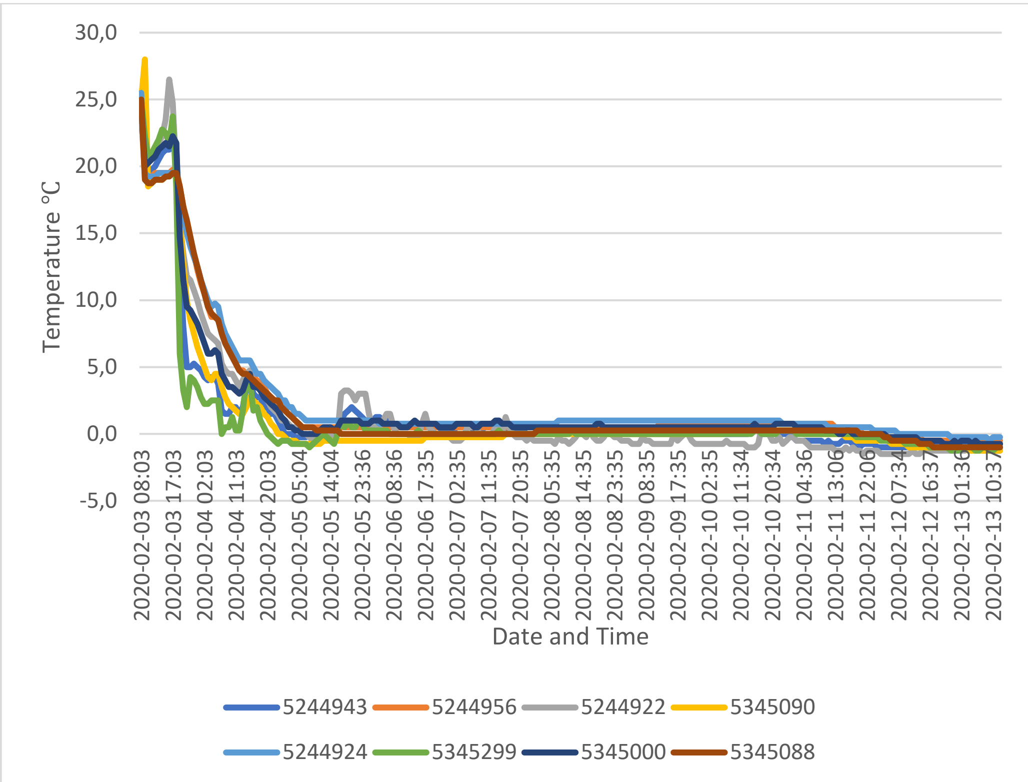


Figure 4.69: Eight device temperature data. Concept B, Trial 2

4.7.2.1 Concept B, Trial 2: Packing stage

Crimson Seedless grapes were packed on 03 February 2020 at Packhouse B. The grapes were packed in B04I cartons, 180 cartons palletised per pallet. Crimson Seedless is a late-season red seedless grape variety, with medium berry size (Dokoozlian, Luvisi, Moriyama & Schrader, 1995:36).

Devices were inserted on 3 February 2020 at 08:00. The grapes were packed at Packhouse B in the Berg River production area. The temperature of the packing area is set at 18 °C. The grapes were moved to a holding area from where they were loaded on a small flatbed truck. The stage from packing to loading on the truck was approximately six hours. Figure 4.70 illustrates the packing stage for Concept B, Trial 2.

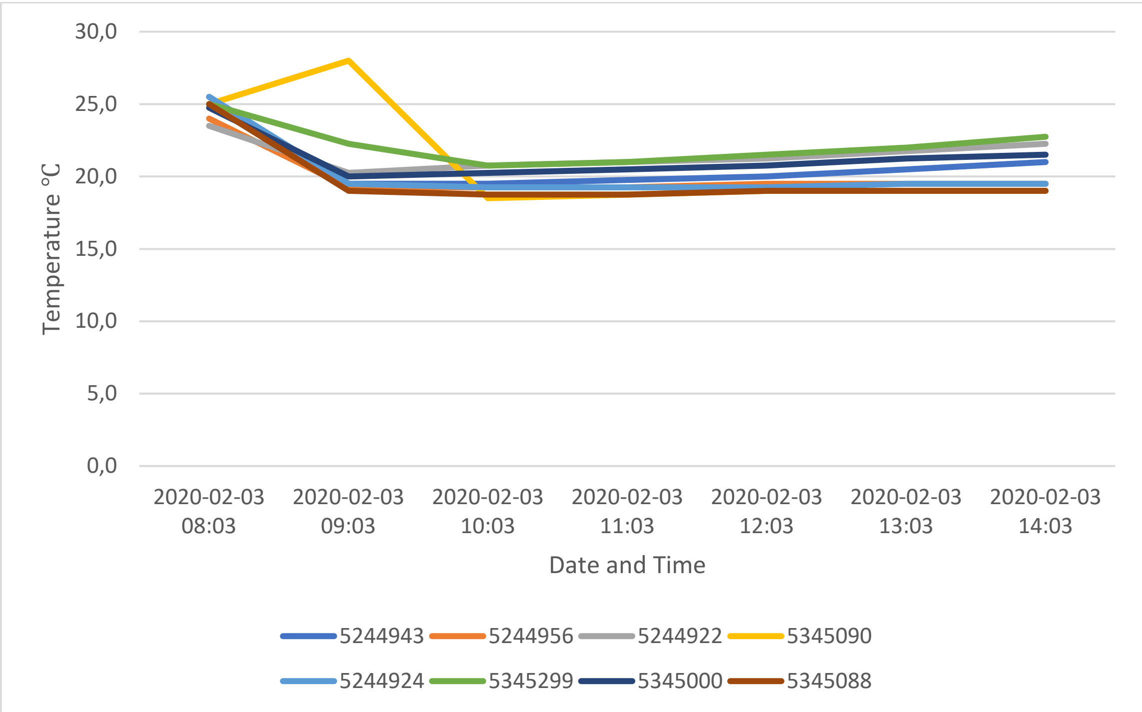


Figure 4.75: Packing stage for Concept B, Trial 2

All eight devices indicated temperature breaks by measuring warmer than 2 °C.. Device 5345090 increased in the first hour, which was due to the repositioning of the device by the researcher. There was a slight increase in temperature due to the movement from the pack line to the holding area.

4.7.2.2 Concept B, Trial 2: Transfer stage from Packhouse B to Cold Storage Facility B

Pallets were collected at 14:30 and transported to Cold Storage Facility B. Including all the operational functions, the complete transfer stage took three hours until pallets were placed under forced-air cooling.

The transfer stage from Packhouse B to Cold Storage Facility B is illustrated in Figure 4.71.

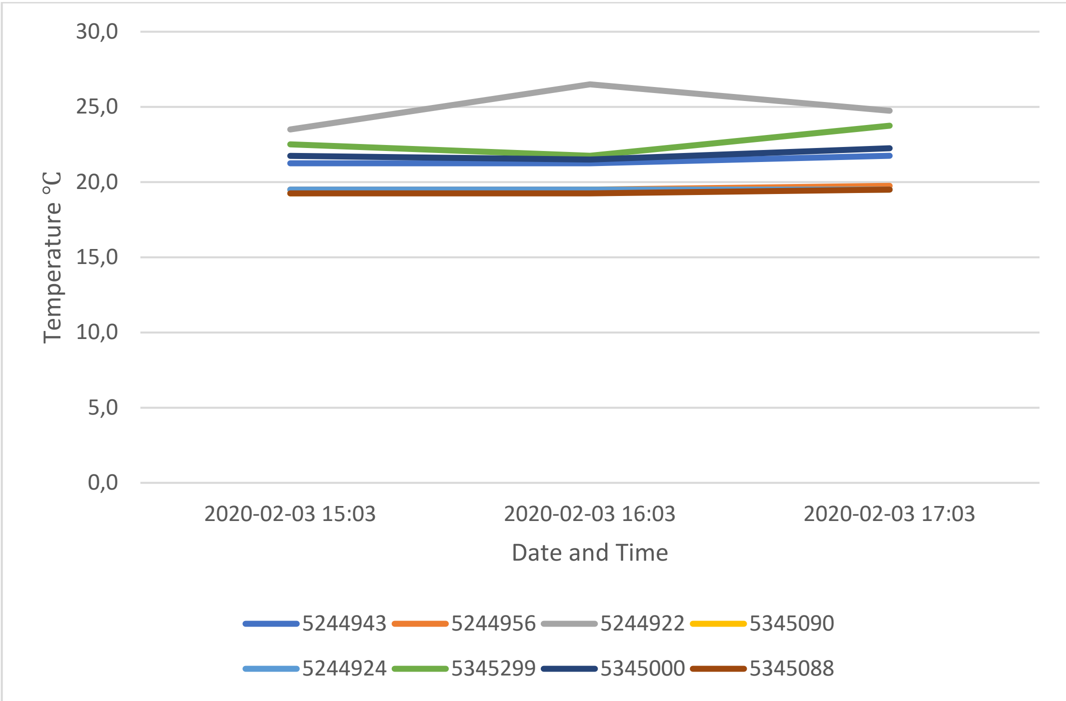


Figure 4.71: Transfer stage from Packhouse B to Cold Storage Facility B. Concept B, Trial 2

All eight devices indicated temperature breaks due to fruit being warner than 2 °C. Temperature increases occurred due to the warmer outside temperature during the transport segment.

4.7.2.3 Concept B, Trial 2: Forced-air cooling stage

Pallets were offloaded under a covered area and moved to a forced-air cooling tunnel. Cold Storage Facility B does not use the step-down cooling procedure. Cold Storage Facility B sets the setpoint of the forced-air cooling room to -1.5 °C from the beginning of the forced-air cooling stage.

Pallets of Trial 2 were in the forced-air cooling tunnel for only 41 hours. Thereafter, the pallets were moved to a holding room where the grapes were stored for four hours before they were loaded to Cold Treatment Facility B.

Figure 4.72 depicts the temperature data of the first 41 hours of forced-air cooling, as the first 48 hours is seen as best practice to get fruit under -0.5 °C.

Figure 4.737 illustrates the temperature data of the 45 hours the pallets were stored and handled at Cold Storage Facility B.

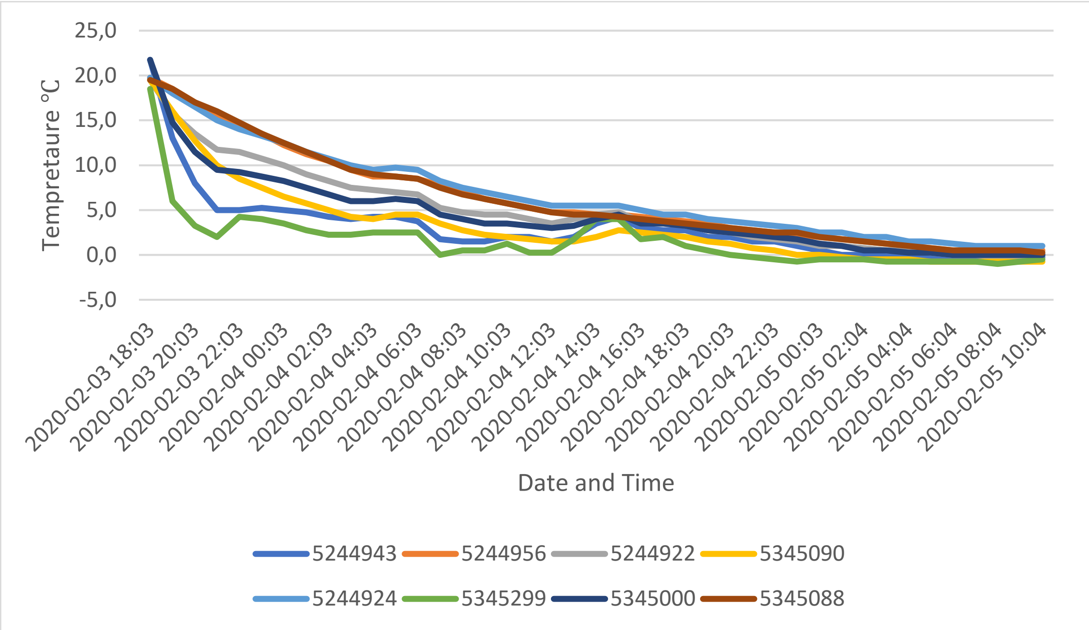


Figure 4.72: Forced-air cooling stage for Concept B, Trial 2

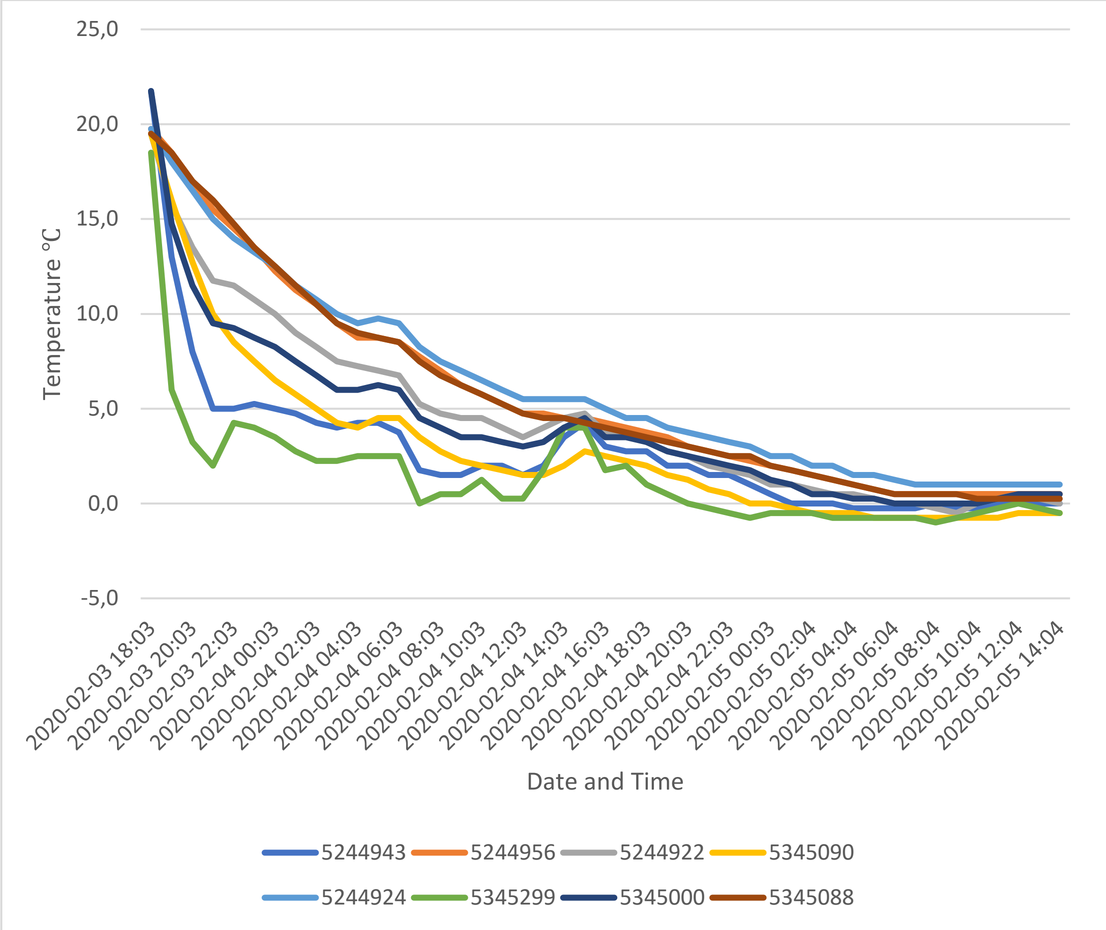


Figure 4.73: Temperature data for Cold Storage Facility B. Concept B, Trial 2

All eight devices indicated temperature breaks for the first 28 hours of the forced-air cooling stage, by measuring 2 °C and warmer. Device 5345299 indicated two temperature breaks. The first temperature break occurred on 3 February 2020 at 22:03 when the temperature reading increased from 2 °C to 4.3 °C. The temperature break lasted for two hours. The break was caused by warm pallets being added to the forced-air cooling room. The second temperature break occurred on 4 February 2020 at 14:03 when the temperature reading increased from 1.8 °C to 4 °C. This temperature break also lasted for two hours. The average temperature data of the eight devices for the period the grapes were handled and stored at Cold Storage Facility B are illustrated in Figure 4.74.

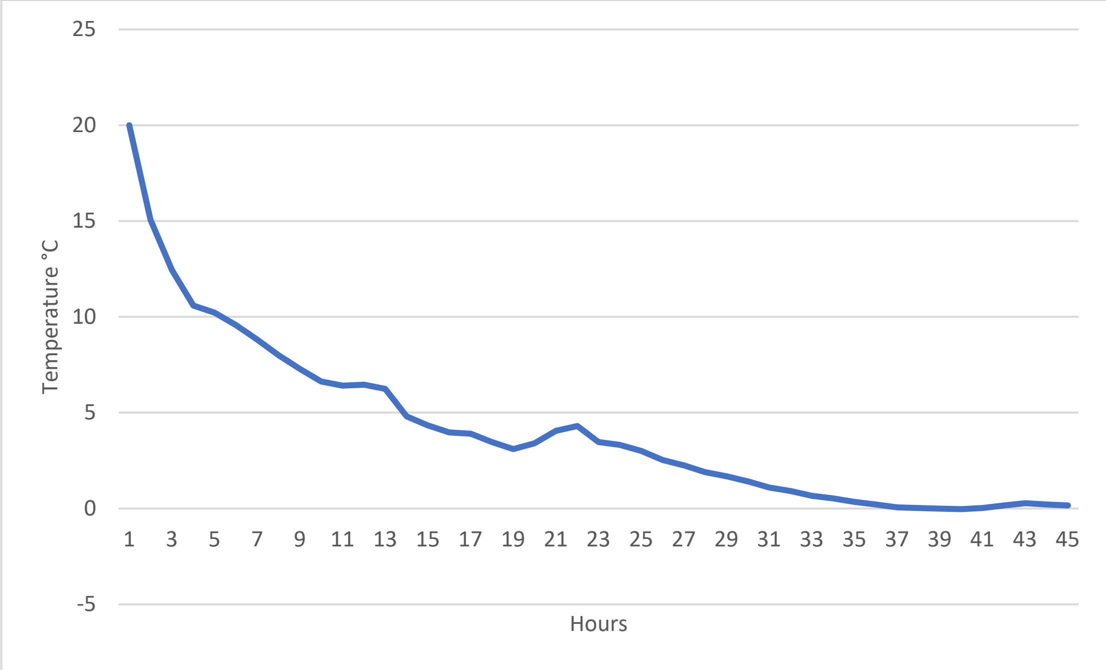


Figure 4.74: Average temperature data for Cold Storage Facility B. Concept B, Trial 2

Only two devices measured a temperature of -0.5 °C and below after the 45 hours of forced-air cooling.

4.7.2.4 Concept B, Trial 2: Transfer stage from Cold Storage Facility B to Cold Treatment Facility B

Pallets were loaded on 05 February 2020 at 15:10 into a refrigerated truck set at 0 °C. It is a two-hour drive from Cold Storage Facility B to Cold Treatment Facility B. Including the operational functions that need to take place, it took six hours until the fruit was standing in a holding room at Cold Treatment Facility B for Concept B, Trial 2.

Figure 4.75 illustrates the temperature data of the transfer stage from Cold Storage Facility B to Cold Treatment Facility B for Concept B, Trial 2.

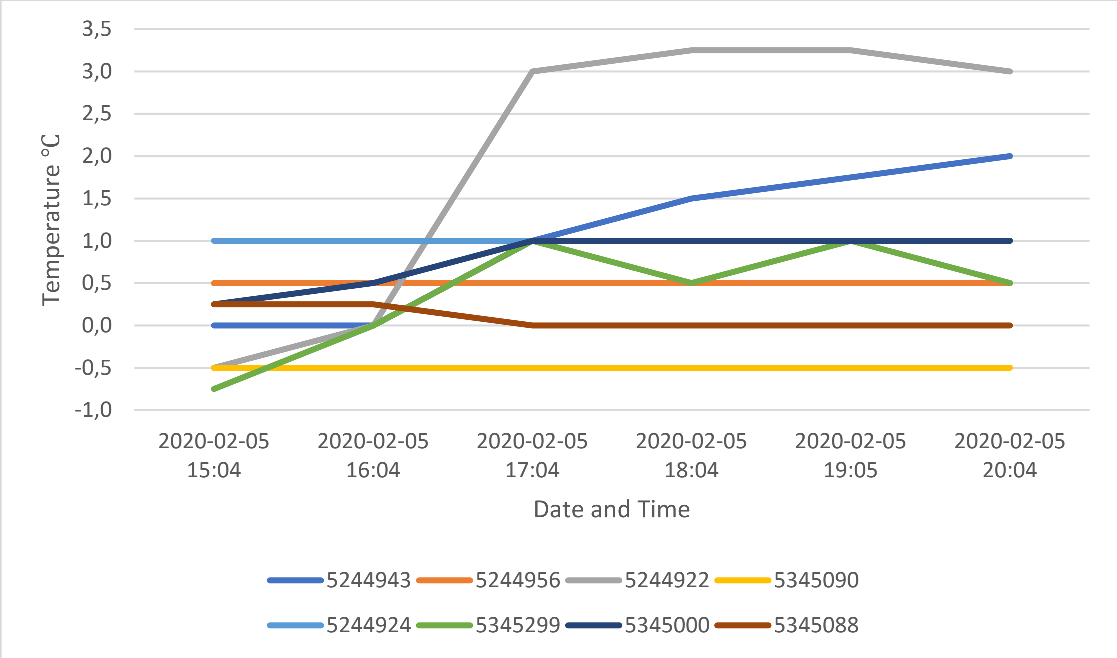


Figure 4.75: Transfer stage from Cold Storage Facility B to Cold Treatment Facility B. Concept B, Trial 2

Device 5244922 indicated a temperature break at 17:04 on 5 February 2020. The temperature break lasted for eight hours.

Three other devices indicated temperature increases from 17:04. The pallets were offloaded at Cold Treatment Facility B at 17:00 and stood in the airlocked area for three hours until the pallets were moved to a holding area. This is not normal activity, but due to peak volumes, the cold treatment facility was under pressure that caused the pallets to stand for a long period in the airlocked area. The airlocked area at Cold Treatment Facility B does not serve as a holding room as temperature seldom gets colder than 5 °C.

4.7.2.5 Concept B, Trial 2: Storage and inspection stage

Cold Storage Facility B stores the pallets in a holding room until the phytosanitary inspection is completed. After the inspection, the pallets are moved to a Steri tunnel where the pre-cooling cold treatment process starts. Pallets were stored in the holding room for 120 hours before they were moved to a Steri tunnel. Figure 4.76 illustrates the 120 hours the fruit was stored in a holding room.

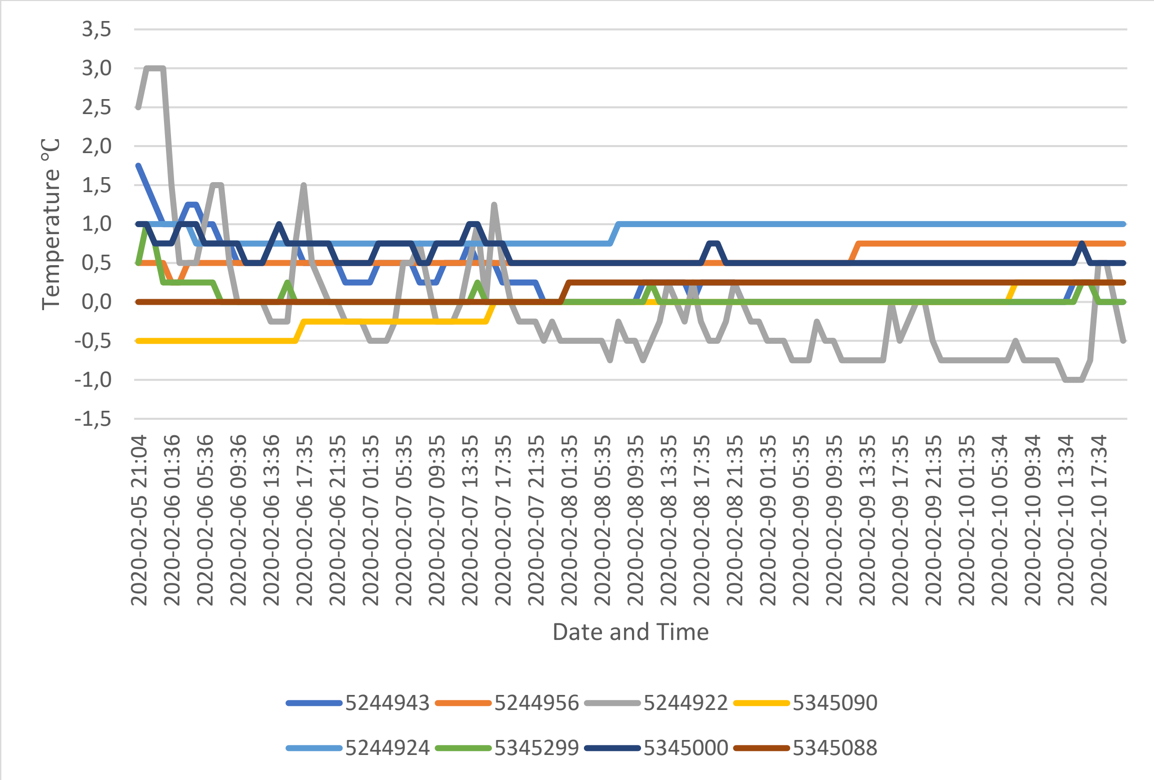


Figure 4.76: Holding stage at Cold Storage Facility B. Concept B, Trial 2

One temperature break was identified at the start of the stage. Temperature increases did occur due to samples being drawn, movement in and out of the holding room and samples being placed back onto the pallets.

4.7.2.6 Concept B, Trial 2: Steri stage

Pallets were packed and passed for the Vietnamese market. The cold treatment protocol states that for Vietnam, the fruit only needs to be at a target temperature of -0.5 °C and in Steri for a minimum of 12 hours. For Concept B, Trial 2 the fruit was in Steri for 63 hours due to vessel stacks moving out. Figure 4.77 illustrates the 63-hour temperature data of the Steri stage for Concept B, Trial 2. Figure 4.78 illustrates the last 12 hours of the Steri stage for Concept B, Trial 2. Unfortunately, the researcher could not retrieve the fruit pulp sensor data that were in the Steri tunnels.

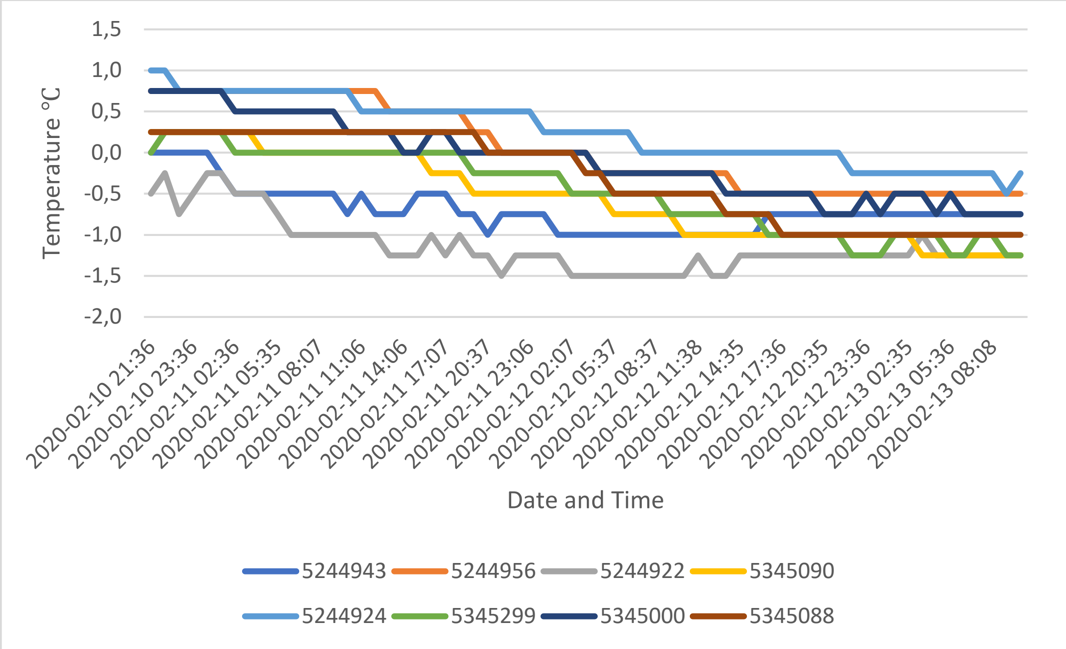


Figure 4.77: Steri stage for Concept B, Trial 2

One temperature break was identified by measuring -1.5 °C. Temperature increases did occur due to frequent defrost cycles.

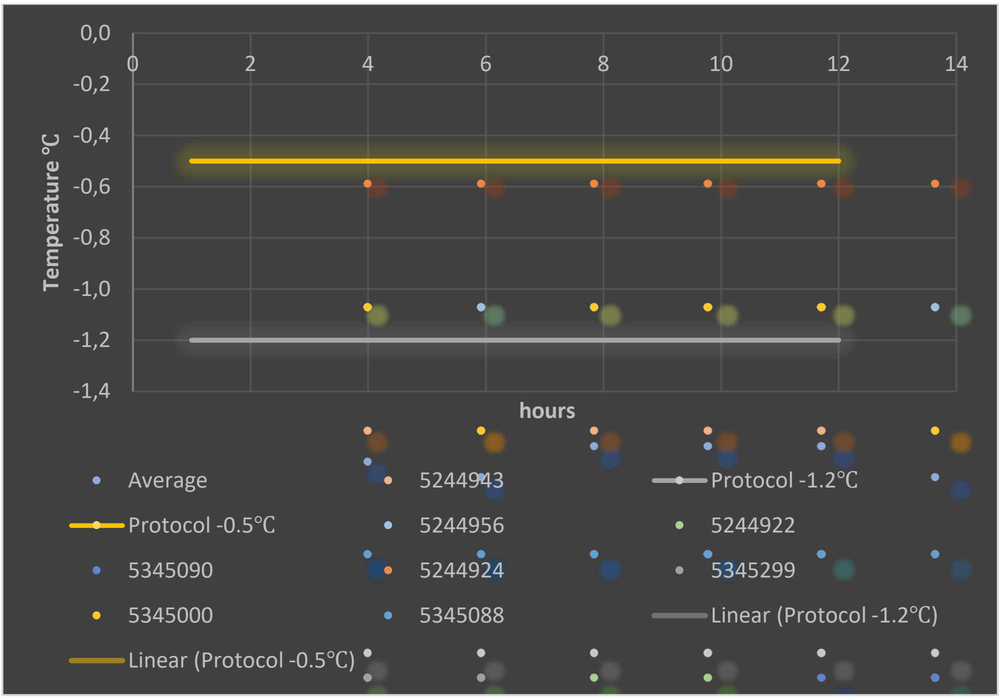


Figure 4.78: 12-hour Steri stage for Concept B, Trial 2

Four devices did not meet the protocol, three devices being colder than -1.2 °C and one being warmer than -0.5 °C. However, no temperature break was identified.

4.7.2.7 Concept B, Trial 2: Loading stage

Grapes were loaded into container CXRU1070878 on 13 February 2020. Loading started at 11:40 and finished at 12:15.

The temperature data of the loading stage is illustrated in Table 4.8. Unfortunately, the researcher could not obtain any information regarding the stacking and shipping stage as the cold storage facility in Vietnam did not have an Xsense receiver installed.

Table 4.8: Temperature data of the loading stage for Concept B, Trial 2

Date and Time	Average	5244943	5244956	5244922	5345090	5244924	5345299	5345000	5345088
2020-02-13 11:37	-0.8	-0.8	-0.5	-1.3	-1.3	-0.3	-1.0	-0.8	-1.0
2020-02-13 12:06	-0.8	-0.8	-0.5	-1.3	-1.3	-0.3	-1.0	-0.8	-1.0

4.7.3 Concept B, Trial 3

Trial 3 of Concept B gathered data from the Berg River production area and not the Hex River production area. However, the concept is the same as grapes were packed at Packhouse B, transported to Cold Storage Facility B and after the forced-air cooling stage, transported to Cold Treatment Facility B.

Eight devices were used for this trial and grapes were packed for China. The eight devices were divided between pallets. Device numbers 5345042, 5244980, 5345049 and 5244972 were inserted into pallet ID 360095142001912210. Device numbers 5244920, 5244952, 5345067 and 5244939 were inserted into pallet ID 360095142001912227.

The average temperature data for Concept B, Trial 3 are illustrated in Figure 4.79 and temperature data of the eight devices are illustrated in Figure 4.80.

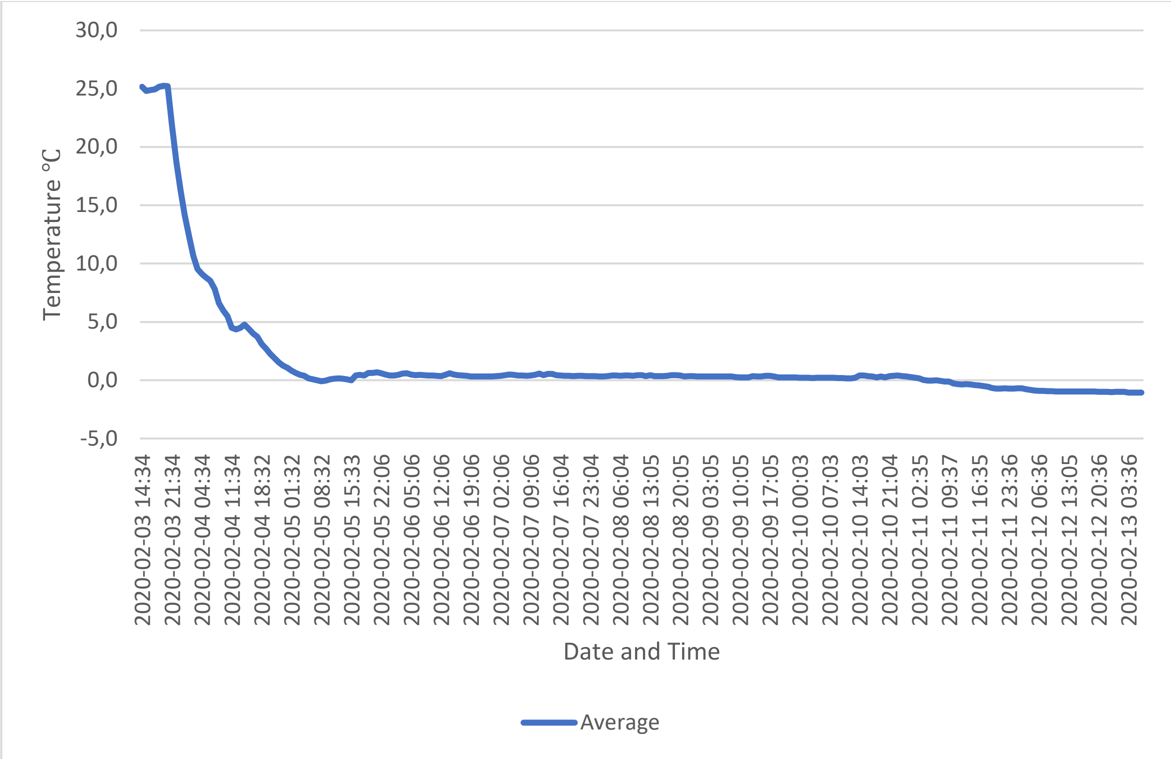


Figure 4.79: Average temperature data for Concept B, Trial 3

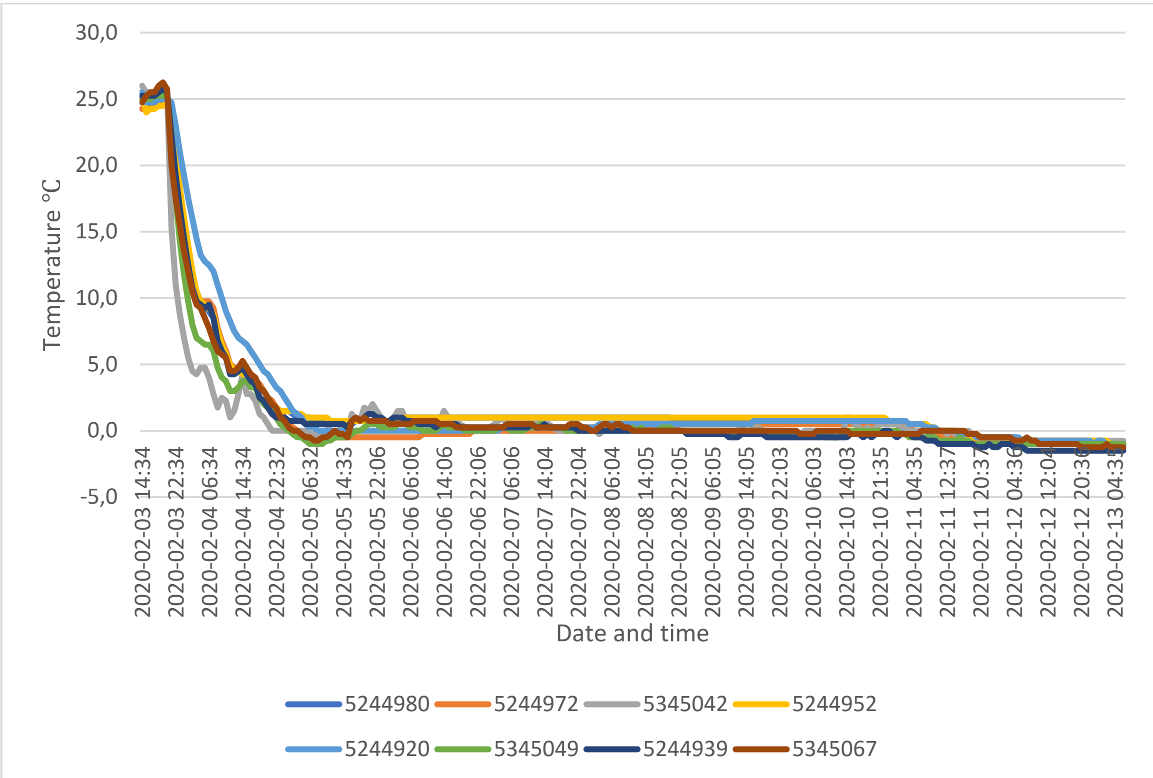


Figure 4.80: Temperature data for Concept B, Trial 3

4.7.3.1 *Concept B, Trial 3: Packing stage*

Crimson Seedless grapes were packed on 03 February 2020 at Packhouse B.

Devices were inserted on 3 February 2020 at 14:30. The grapes were packed at Packhouse B in the Berg River production area. The temperature of the packing area is set at 18 °C. The grapes were moved to a holding area from where they were loaded onto a small flatbed truck. The stage from packing to being loaded onto the truck took approximately six hours.

Figure 4.81 illustrates a line diagram of the packing stage for Concept B, Trial 3.

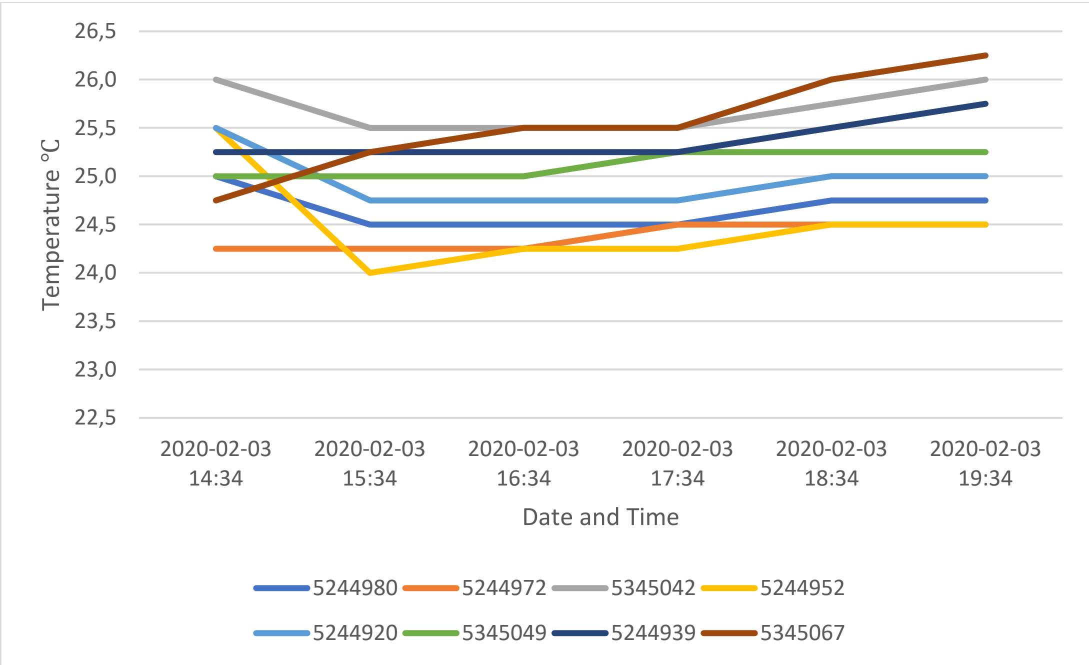


Figure 4.81: Packing stage for Concept B, Trial 3

All eight devices indicated temperature breaks due to the temperature being warmer than 2 °C. There was a slight increase in temperature due to the movement from the pack line to the holding area.

4.7.3.2 *Concept B, Trial 3: Transfer stage from Packhouse B to Cold Storage Facility B*

Pallets were collected at 19:45 and transported to Cold Storage Facility B. Including all operational functions, the complete transfer stage took two hours until pallets were placed under forced-air cooling.

The transfer stage from Packhouse B to Cold Storage Facility B is illustrated in Figure 4.82.

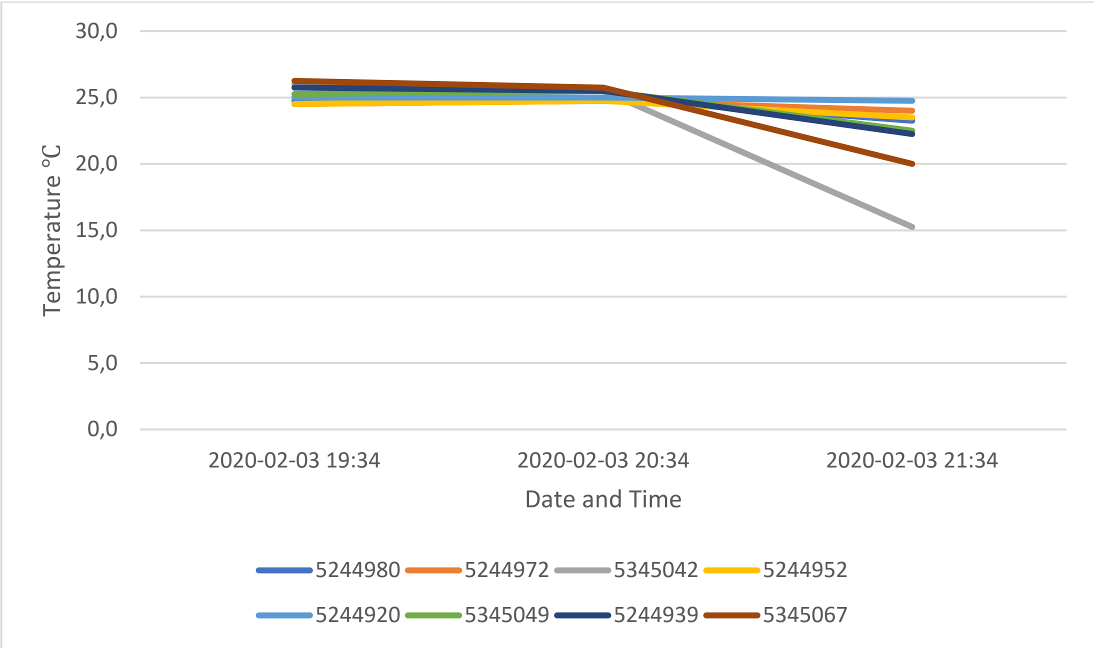


Figure 4.82: Transfer stage from Packhouse B to Cold Storage Facility B. Concept B, Trial 3

All eight devices indicated temperature breaks. All the devices had a decrease in temperature reading when the pallets were offloaded and moved into the cold storage facility.

4.7.3.3 Concept B, Trial 3: Forced-air cooling stage

Pallets were placed under forced-air cooling immediately after arrival.

Pallets of Trial 2 were in the forced-air cooling tunnel for only 41 hours. The pallets were loaded directly from the forced-air cooling tunnel to Cold Treatment Facility B.

Figure 4.83 illustrates the temperature data of the 41 hours of forced-air cooling.

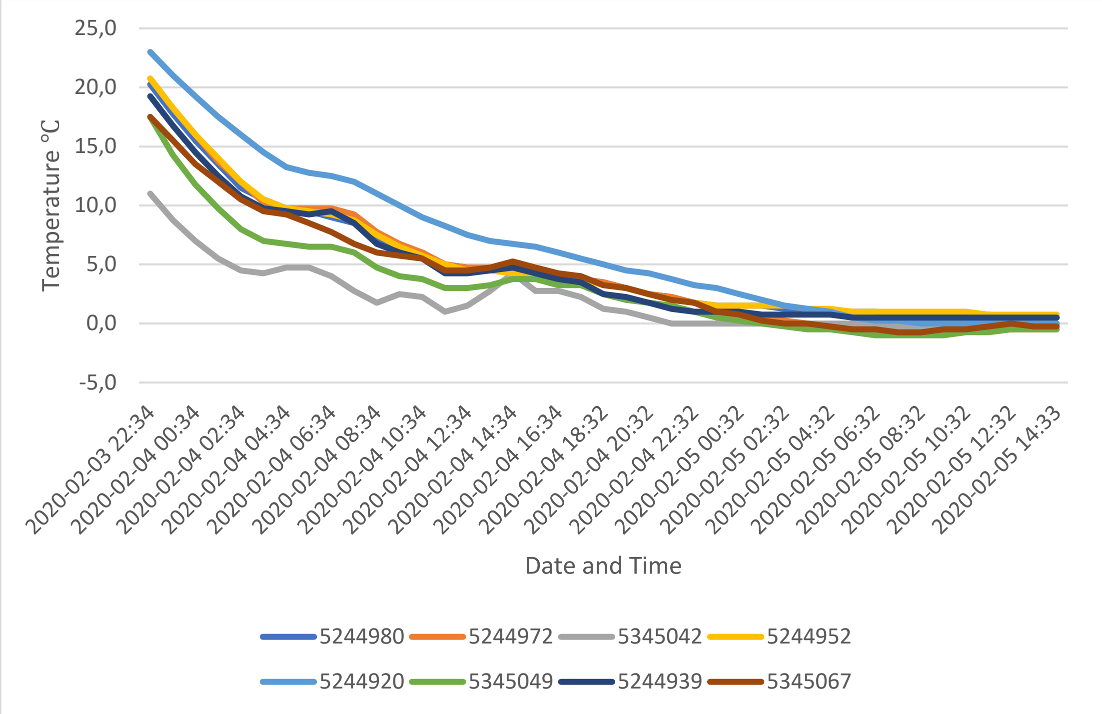


Figure 4.83: Forced-air cooling stage for Concept B, Trial 3

All eight indicated temperature breaks for the first 24 hours of the stage.

Only two devices were under -0.5 °C after the 41 hours of forced cooling.

4.7.3.4 Concept B, Trial 3: Transfer stage from Cold Storage Facility B to Cold Treatment Facility B

Pallets were loaded on 05 February 2020 at 15:10 into a refrigerated truck set at 0 °C. Although it is only a two-hour drive from Cold Storage Facility B to Cold Treatment Facility B, including the operational functions that needed to take place, it took six hours before the fruit was standing in a holding room at Cold Treatment Facility B.

Figure 4.84 illustrates the temperature data of the transfer stage from Cold Storage Facility B to Cold Treatment Facility B for Concept B, Trial 3.

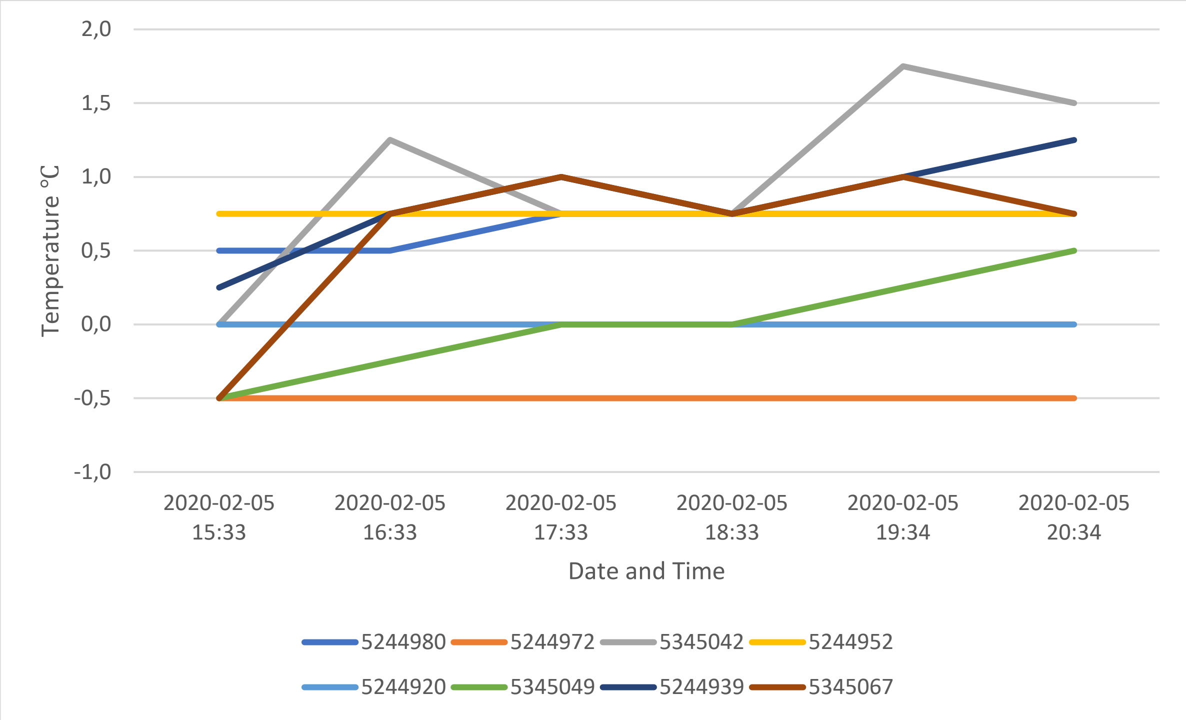


Figure 4.84: Transfer stage from Cold Storage Facility B to Cold Treatment Facility B. Concept B, Trial 3

No temperature breaks were identified. Temperature increases did occur due to pallets standing in the airlocked area before being transferred to the holding room.

4.7.3.5 Concept B, Trial 3: Storage and inspection stage

Pallets are stored in a holding room until the phytosanitary inspection has been completed. After inspection, the pallets are moved to a Steri tunnel where the pre-cooling cold treatment process will start. Pallets were stored in the holding room for 122 hours before they were moved to a Steri tunnel. Figure 4.85 illustrates the 122 hours the fruit was stored in a holding room.

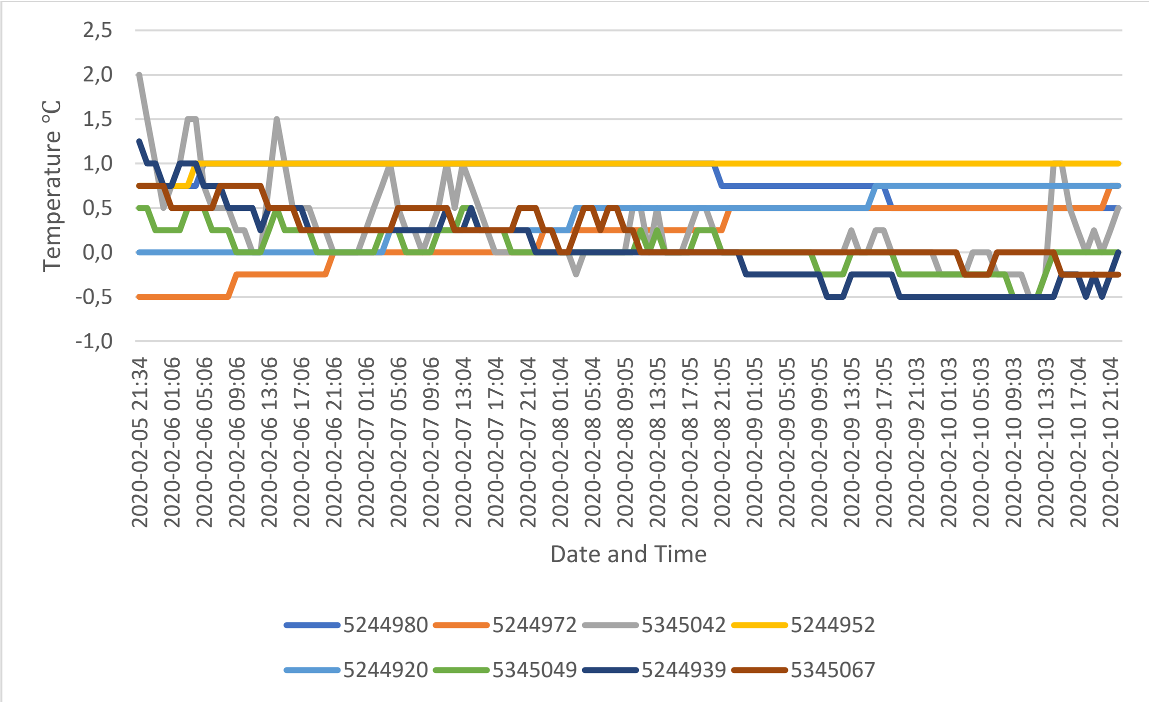


Figure 4.85: Storage and inspection stage for Concept B, Trial 3

One temperature spike did occur in the start of the stage. Fluctuations in temperature occurred due to samples being drawn, movement in and out of the holding room and samples being placed back into the pallets.

The average temperature for the storage and inspection stage is illustrated in Figure 4.86.

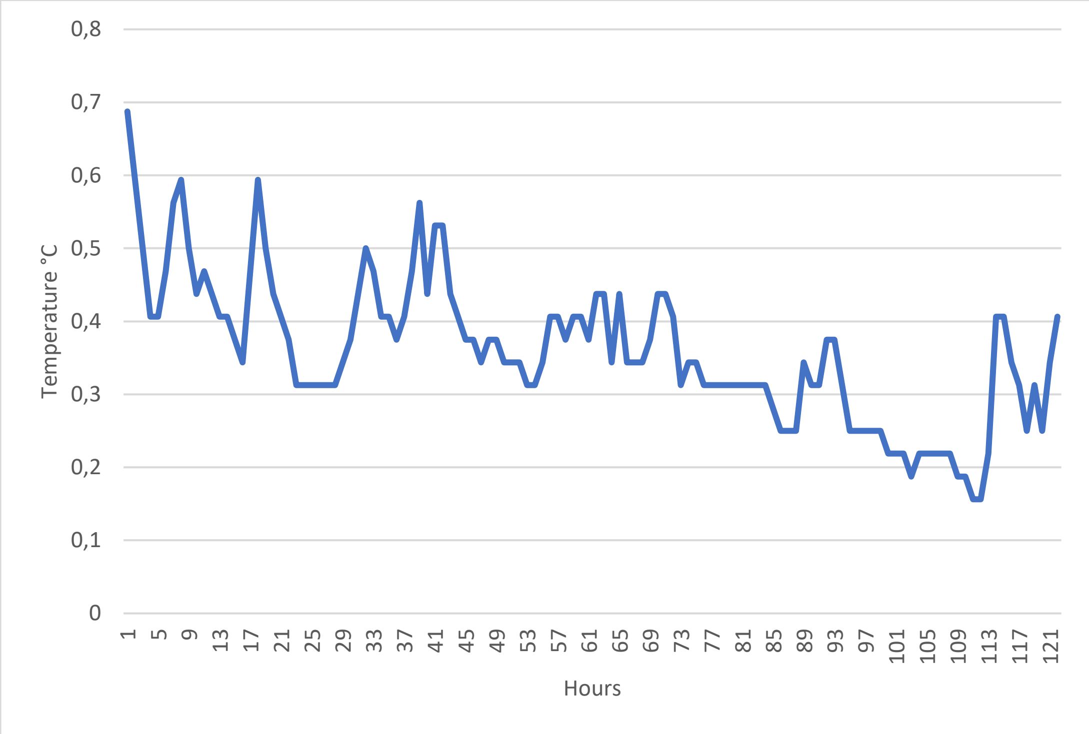


Figure 4.86: Storage and inspection stage of Concept B, Trial 3

Fluctuation in temperature can be seen clearly in Figure 4.86.

4.7.3.6 Concept B, Trial 3: Steri stage

Pallets were packed and passed for China. For Concept B, Trial 3 the fruit was in Steri for 54 hours due to vessel stacks moving out.

Figure 4.87 illustrates the 54-hour temperature data of the Steri stage for Concept B, Trial 3.

Figure 4.88 illustrates the last 24 hours of the Steri stage for Concept B, Trial 3.

A scatter chart of the last six hours of the Steri stage is illustrated in Figure 4.89.

Unfortunately, the researcher could not retrieve the fruit pulp sensor data in the Steri tunnels.

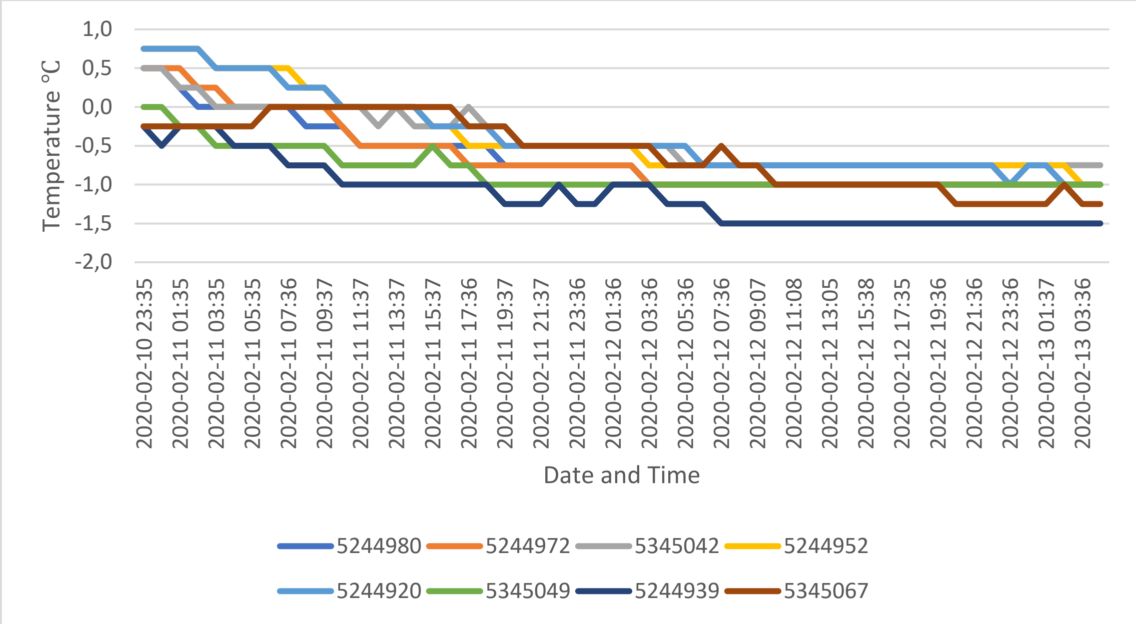


Figure 4.87: Steri stage for Concept B, Trial 3

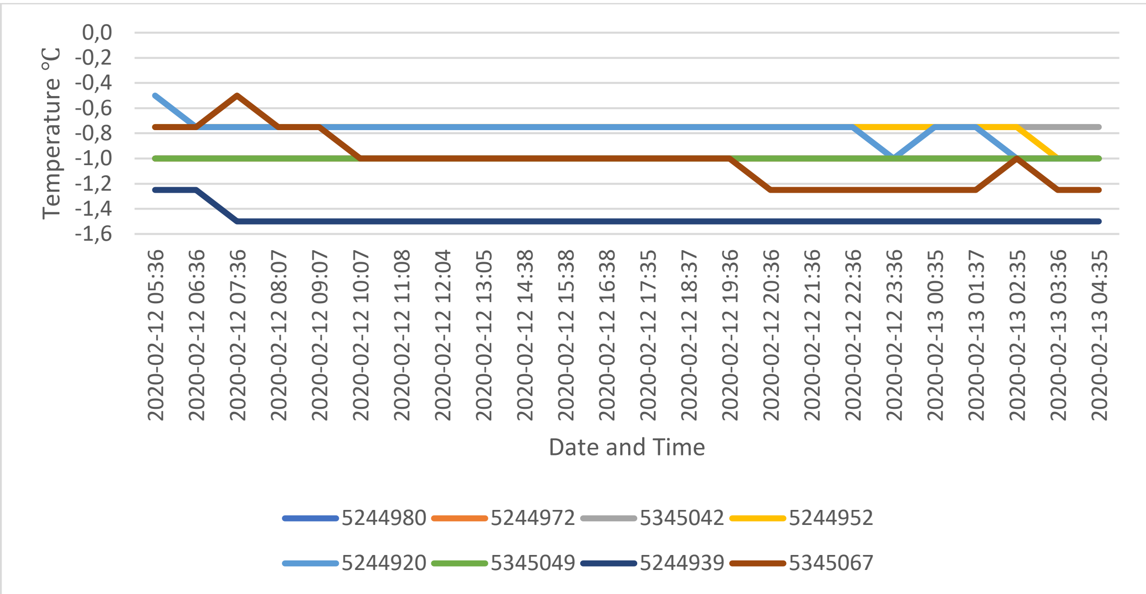


Figure 4.88: 24-hour Steri stage for Concept B, Trial 3

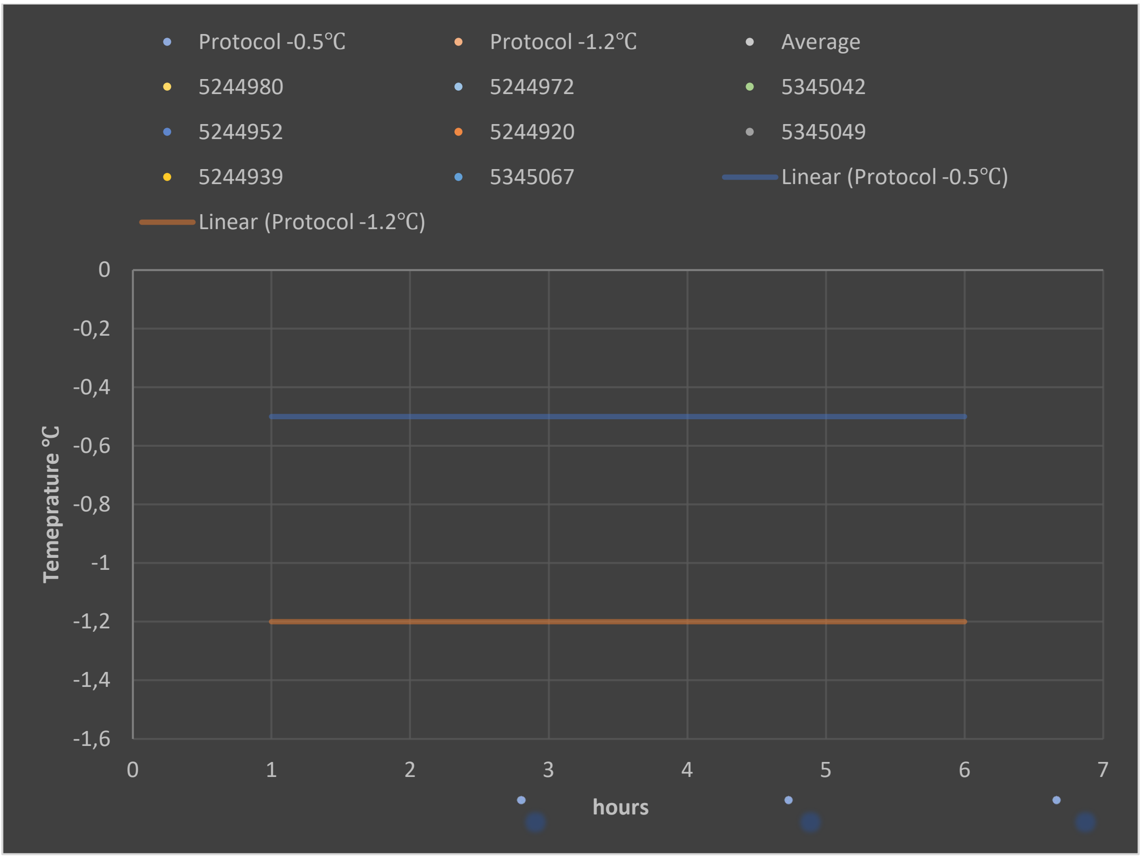


Figure 4.89: Last six hours of the Steri stage for Concept B, Trial 3

Two devices did not meet the protocol, being colder than -1.2 °C. The setpoint of the room is set at -1.5 °C as per the PPECB protocol. One temperature break was identified by measuring -1.5 °C.

4.7.3.7 Concept B, Trial 3: Loading stage

Grapes were loaded into container TEMU9361503 on 13 February 2020. Loading started at 05:40 and finished at 06:15. The temperature data of the loading stage is illustrated in Table 4.9.

Table 4.9: Temperature data of the loading stage for Concept B, Trial 3

Date and Hours	Average	5244980	5244972	5345042	5244952	5244920	5345049	5244939	5345067
2020-02-13 05:37	-1.1	-1.0	-1.0	-0.8	-1.0	-1.0	-1.0	-1.5	-1.3
2020-02-13 06:37	-1.1	-1.0	-1.0	-0.8	-1.0	-1.0	-1.0	-1.5	-1.3

The researcher was unable to gather the temperature data for the shipping stage.

4.7.4 Concept B, Trial 4

Trial 4 was conducted in the Hex River production area. Devices were inserted at Packhouse A, transferred to Cold Storage Facility A, then transferred to Cold Treatment Facility A and loaded to China.

Twelve devices were divided between three pallets. Pallet ID 360091600186289786 had devices 5244986, 5345031, 5244936 and 5244988. Pallet ID 360091600186289762 had devices 5244983, 5244982, 5345093 and 5244960. Pallet ID 360091600186289779 had devices 5345013, 5244944, 5245003 and 5245004.

Figure 4.90 illustrates the average temperature of Concept B, Trial 4.

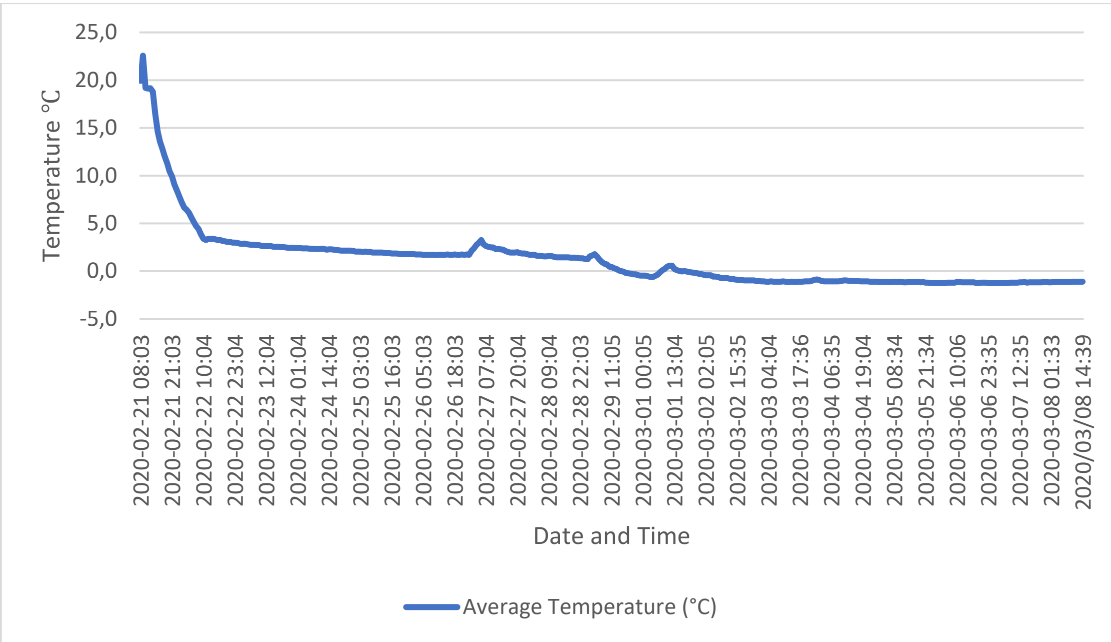


Figure 4.90: Average temperature data for Concept B, Trial 4

The temperature data of all 12 devices are illustrated in Figure 4.91.

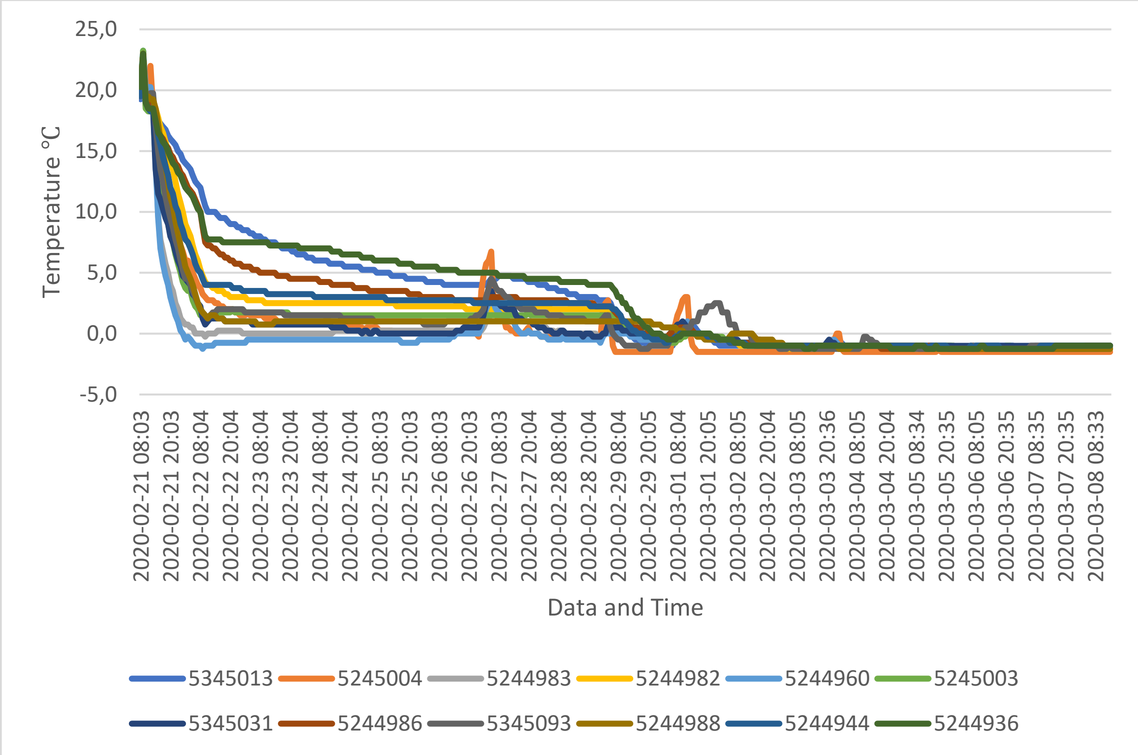


Figure 4.91: Temperature data for Concept B, Trial 4

4.7.4.1 Concept B, Trial 4: Packing stage

Crimson seedless grapes were packed on 21 February 2020 at Packhouse A in B04I cartons, 180 cartons per pallet.

The devices were inserted at 08:00 in the morning of 21 February 2020 at Packhouse A. After palletising, the pallets were moved to a holding room set at 18 °C. The stage from packing to pallets being transferred to Cold Storage Facility A took six hours and the temperature data for these six hours are illustrated in Figure 4.92.

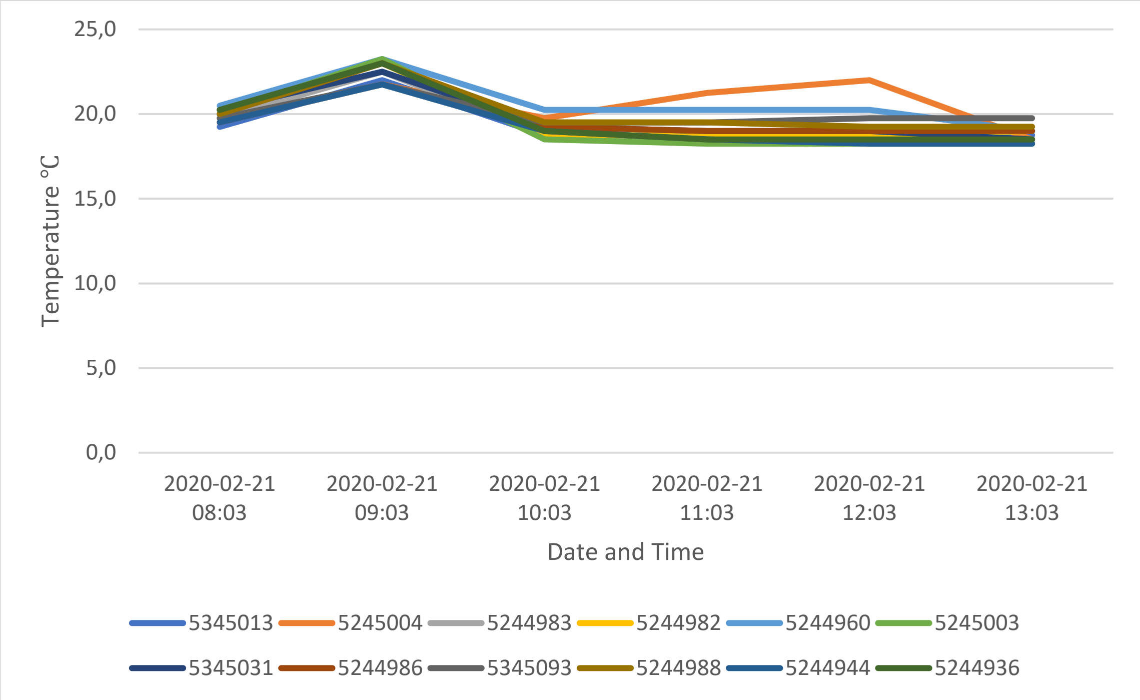


Figure 4.92: Packing stage for Concept B, Trial 4

Temperature increases were identified due to movement of pallets from packing area to holding room. All 12 devices indicated temperature breaks due to measuring warmer than 2 °C.

4.7.4.2 Concept B, Trial 4: Transfer stage from Packhouse A to Cold Storage Facility A

Pallets were loaded on 21 February 2020 at 14:00 onto a small flatbed truck and transported to Cold Storage Facility A. The whole process from pallets being loaded onto the truck to pallets being moved to the forced-air cooling room, took two hours. The temperature data for the transfer stage are illustrated in Table 4.10.

Table 4.10: Temperature data of the transfer stage from Packhouse A to Cold Storage Facility A. Concept B, Trial 4

Date and Time	Average Temperature (°C)	5345013	5245004	5244983	5244982	5244960	5245003	5345031	5244986	5345093	5244988	5244944	5244936
2020-02-21 14:03	16.6	18.3	16.0	14.3	18.5	14.0	16.3	13.5	17.3	17.3	18.5	17.5	17.5
2020-02-21 15:03	14.6	17.5	14.5	9.8	17.8	9.5	13.8	11.5	16.3	15.0	17.3	16.3	16.5

All 12 devices indicated temperature breaks initially. The temperature decreased as soon as the pallets were offloaded and moved to the forced-air cooling rooms.

4.7.4.3 Concept B, Trial 4: Forced-air cooling stage

Cold Storage Facility A does not use the step-down cooling procedure. Cold Storage Facility A sets the setpoint of the forced-air cooling room to -1.5 °C from the beginning of the forced-air cooling stage.

Pallets of Trial 4 were in the forced-air cooling tunnel for 48 hours. Thereafter, the pallets were moved from the forced-air cooling tunnel to a holding room where the grapes were stored for 81 hours before they were loaded to Cold Treatment Facility A.

Figure 4.93 depicts the temperature data of the first 48 hours of forced-air cooling, as the first 48 hours is seen as best practice to cool fruit to under -0.5 °C.

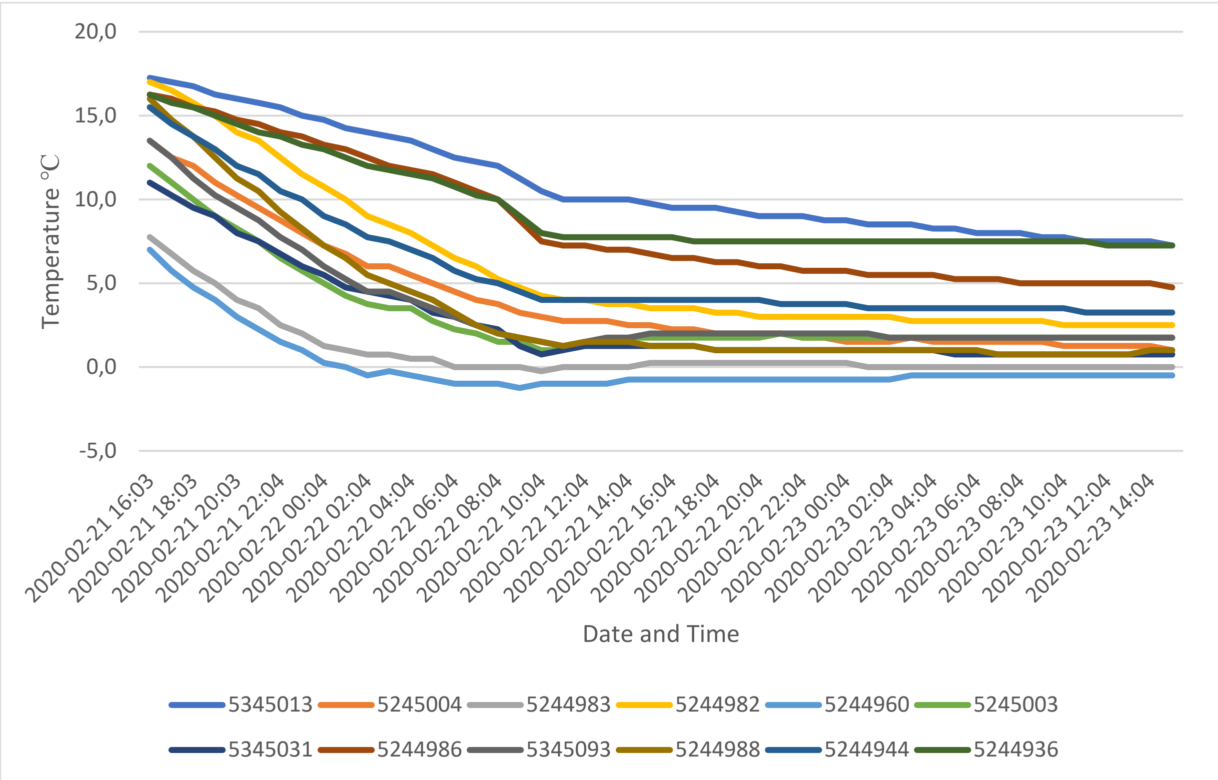


Figure 4.93: 48-hour forced-cooling stage for Concept B, Trial 4

Figure 4.94 illustrates the temperature data of the 129 hours the pallets were stored and handled at Cold Storage Facility A.

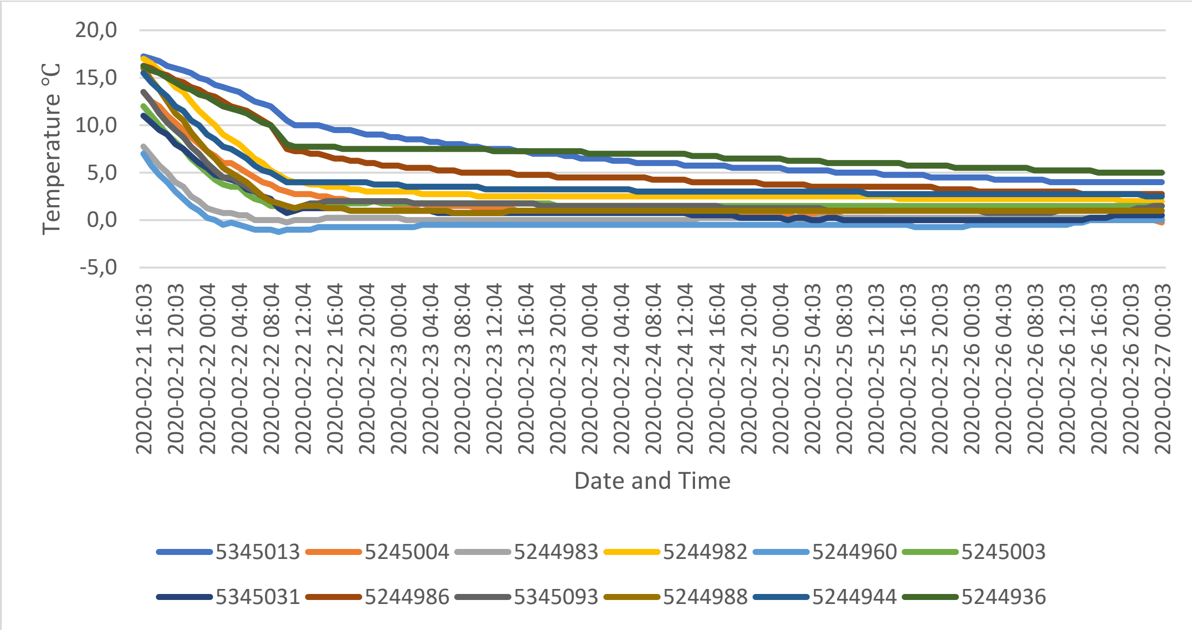


Figure 4.94: Temperature data of the Cold Storage Facility A, Concept B, Trial 4

Not one device measured the desired temperature as per the best practice of -0.5 °C. Pallets were not optimally cooled; only the devices on the outer layer cartons reached colder temperatures. Five devices indicated temperature measurements of above 2 °C, and therefore, are seen as temperature breaks.

4.7.4.4 Concept B, Trial 4: Transfer stage from Cold Storage Facility A to Cold Treatment Facility A

Pallets were loaded on 27 February 2020 at 00:30 on a tautliner truck destined for Cold Treatment Facility A. Pallets arrived at 03:00 and were placed in a holding room at 05:30. The whole process from loading to being stored in a holding room took five hours.

Figure 4.95 illustrates the temperature data measured for the transfer stage from Cold Storage Facility A to Cold Treatment Facility A.

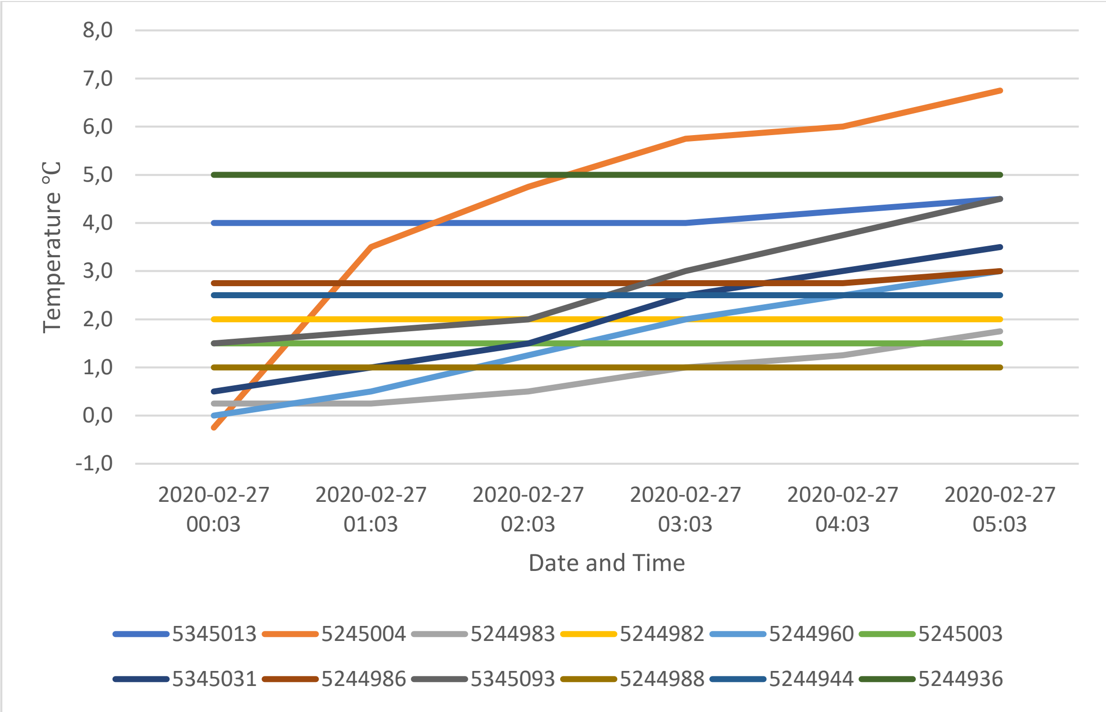


Figure 4.95: Transfer stage from Cold Storage Facility A to Cold Treatment Facility B. Concept B, Trial 4

Device 5245004 indicated a temperature break that lasted six hours. The temperature reading increased from -0.3 °C to 3.5 °C. The maximum temperature reading in the six hours was 6.8 °C. Nine devices indicated temperature breaks by temperature measuring higher than 2 °C.

4.7.4.5 Concept B, Trial 4: Storage and inspection stage

Pallets were placed in a holding room while inspections were conducted. Inspections took place on 27 February 2020, the same day the pallets arrived at Cold Treatment Facility A. Due to the COVID-19 pandemic, the shipping opportunities to the East were less frequent than usual. This delayed the process of placing pallets immediately in Steri tunnels after inspection and pallets were only placed in Steri after a vessel was identified. Pallets of Concept B, Trial 4 were placed in a Steri tunnel on 01 March 2020 at 13:00, 72 hours after inspection. The total period the pallets were stored in a holding room at Cold Treatment Facility A was 80 hours, as illustrated in Figure 4.96.

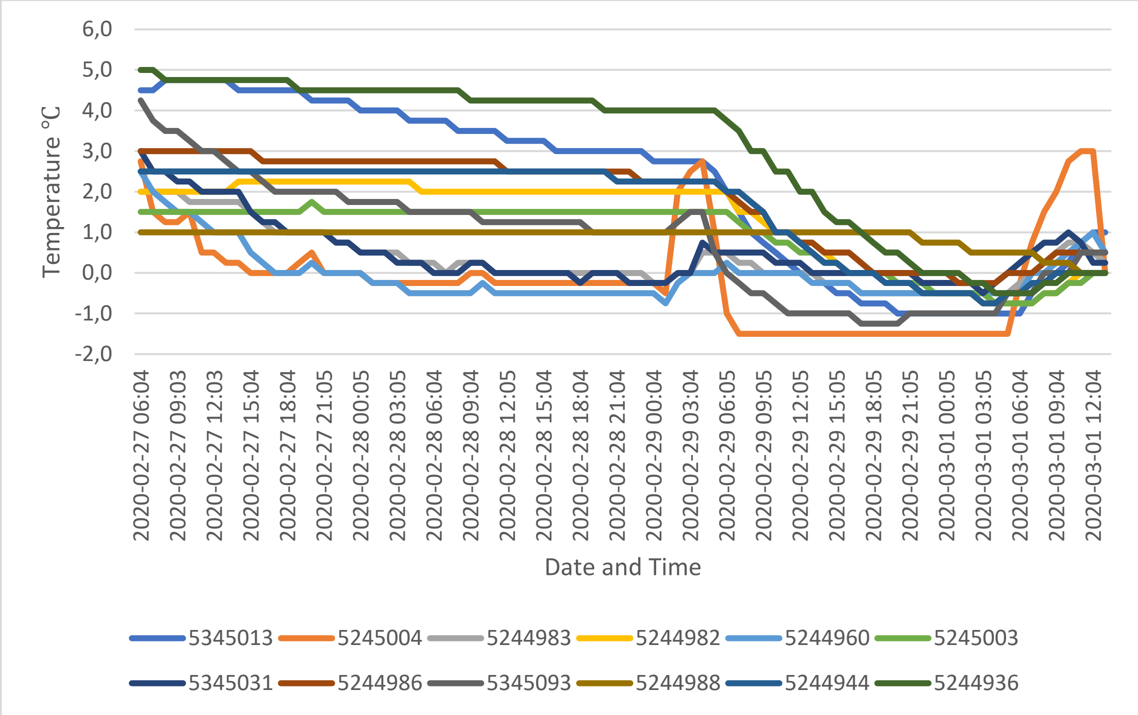


Figure 4.96: Storage and inspection stage, Concept B, Trial 4

Nine temperature breaks and one temperature spike were identified by the devices at the start of the stage, by being 2 °C and warmer.

On 29 February 2020, device 5245004 indicated a temperature break at 02:04 that lasted for three hours. The temperature increased from -0.5 °C to 2 °C, then gradually to 2.8 °C before decreasing to 1 °C. The device also decreased to -1.5 °C on 29 February 202 at 07:05, indicating as temperature break that lasted for 21 hours. Device 5245004 indicated a gradual temperature increase from 07:04 on 01 March 2020 until 13:04.

Figure 4.97 illustrates a line diagram for device 5245004 during the storage and inspection stage.

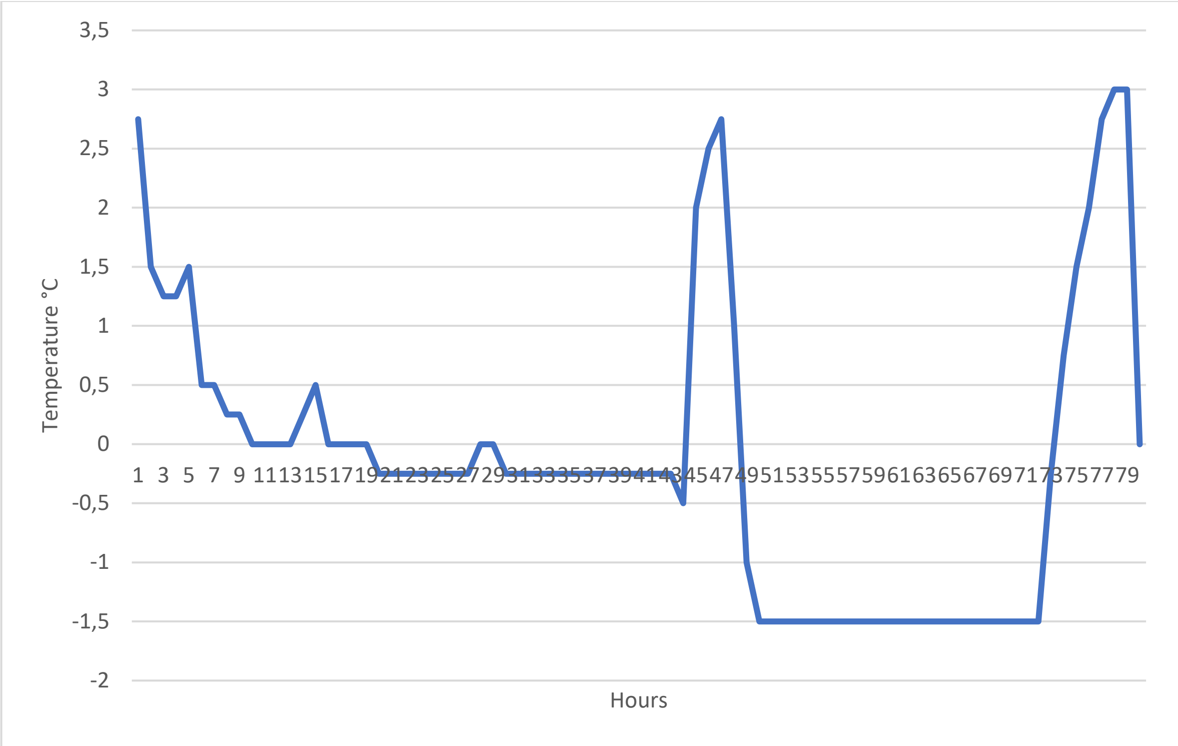


Figure 4.97: Device 5245004 during the storage and inspection stage. Concept B, Trial 4

Temperature fluctuations occurred, which could be due to movement in and out of the holding rooms. The average temperature data for the storing and inspection stage are illustrated in Figure 4.98.

Figure 4.98: Average temperature data during the storage and inspection stage. Concept B, Trial 4

4.7.4.6 Concept B, Trial 4: Steri stage

Pallets were packed and passed for China. Pallets were placed in a Steri tunnel after a vessel was identified, but due to vessel stacks not firming and limited vessels sailing to the East because of the COVID-19 pandemic, the grapes stood in a Steri tunnel for 167 hours.

Figure 4.99 illustrates the 167-hour temperature data of the pallets standing in a Steri tunnel.

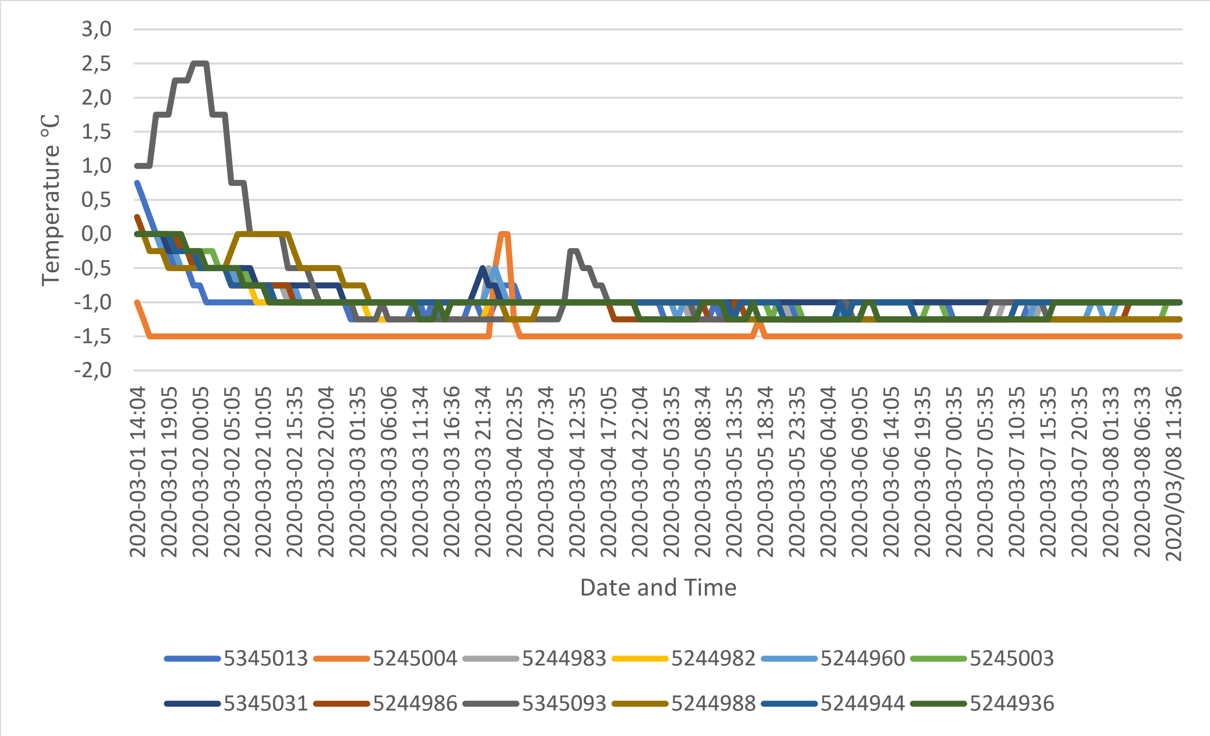


Figure 4.99: 167-hour Steri stage for Concept B, Trial 4

Two temperature breaks occurred, one increasing warmer than 2 °C, due to samples being placed back into the pallet and one decreasing to -1.5 °C, which is the same as the set point of -1.5 °C. Optimum forced-air cooling or Steri management was necessary to limit the air forced over the fruit with fruit standing in Steri for a long period. Too much air forced over the grapes may cause drying of the stems.

Figure 4.100 illustrates the last 24 hours of the Steri stage for Concept B, Trial 4.

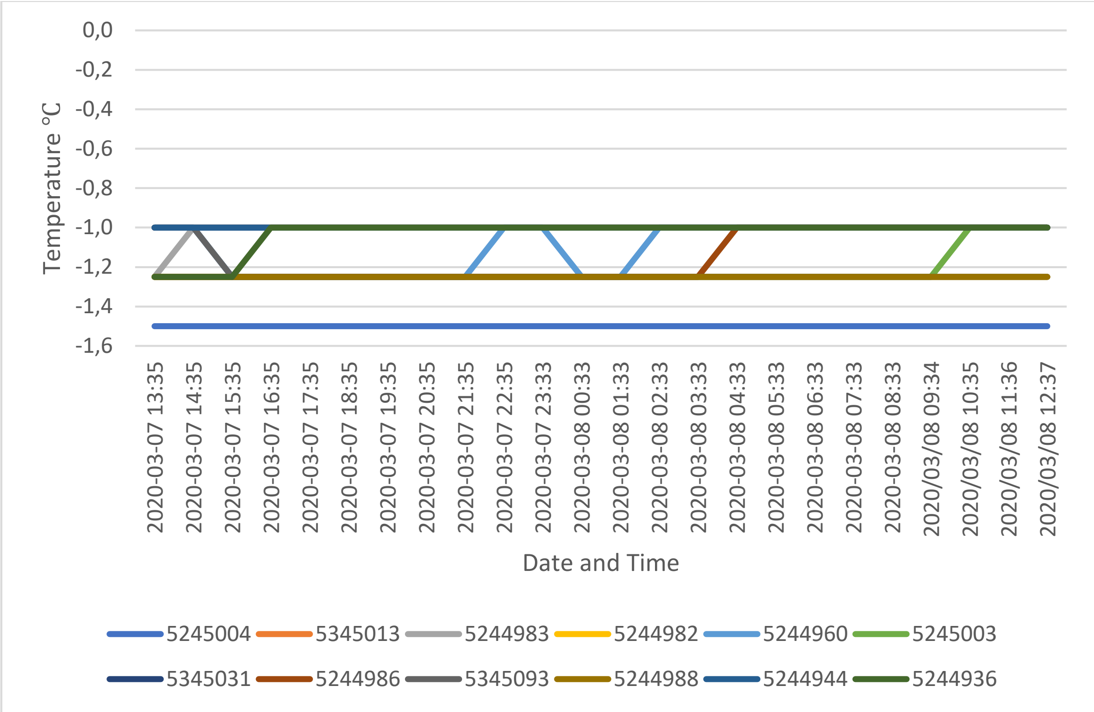


Figure 4.100: 24-hour Steri protocol for Concept B, Trial 4

The last six hours of the Steri stage are illustrated in Figure 4.101.

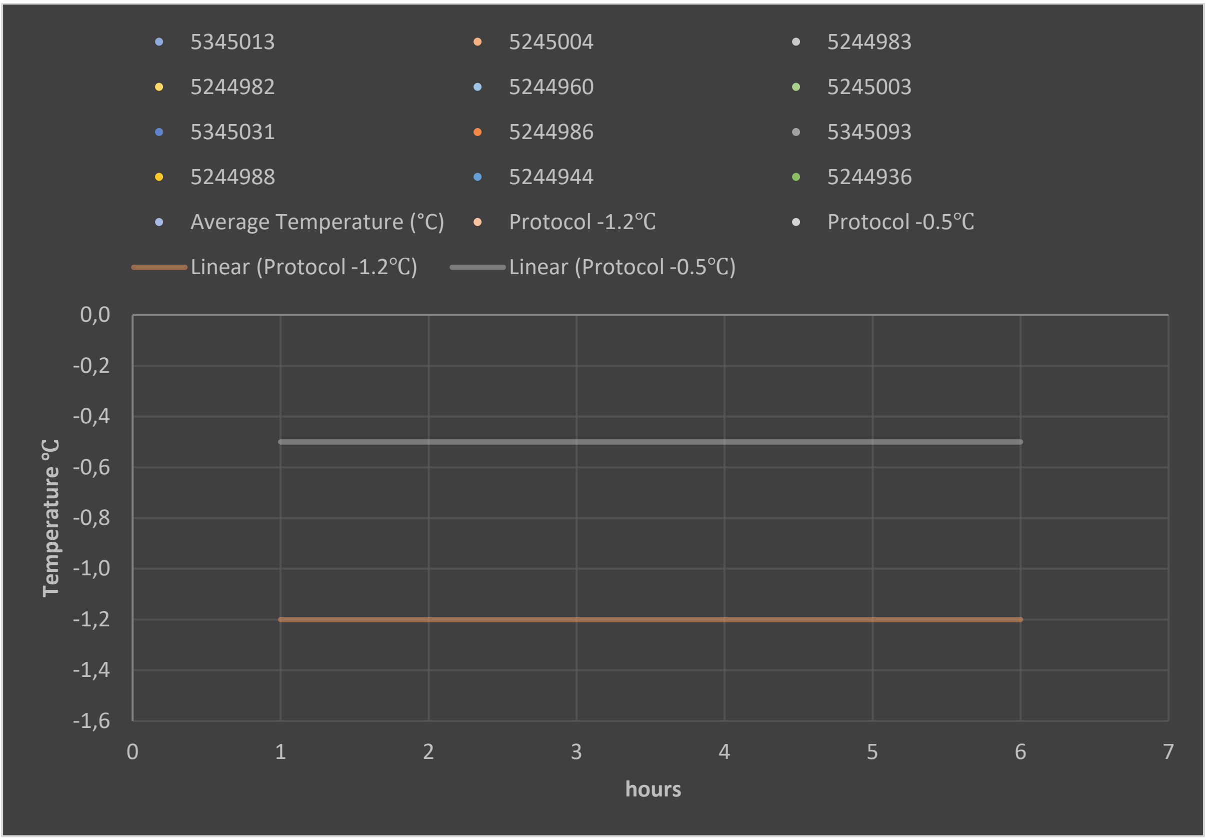


Figure 4.101: Last 6-hour Steri stage for Concept B, Trial 4

Four devices were not within protocol, being colder than -1.2 °C. One temperature break was identified, measuring -1.5 °C.

4.7.4.7 Concept B, Trial 4: Loading stage

Pallets were loaded on 08 March 2020 at 14:00 into container number SZLU9542793.

The temperature data of the loading stage is illustrated in Table 4.11.

Table 4.11: Temperature data of 12 probes during the loading stage

Date and Time	Average Temperature (°C)	5345013	5245004	5244983	5244982	5244960	5245003	5345031	5244986	5345093	5244988	5244944	5244936
2020/03/08 13:38	-1.1	-1.0	-1.5	-1.0	-1.3	-1.0	-1.0	-1.0	-1.0	-1.3	-1.3	-1.0	-1.0
2020/03/08 14:39	-1.1	-1.0	-1.5	-1.0	-1.3	-1.0	-1.0	-1.0	-1.0	-1.3	-1.3	-1.0	-1.0

The researcher could not gather any temperature data of the shipping stage after the container was loaded at Cold Treatment Facility A.

4.7.5 Averages of Concept B

The averages of each trial provide a holistic view of Concept B. Figure 4.102 illustrates the average temperature data of all four trials of Concept B.

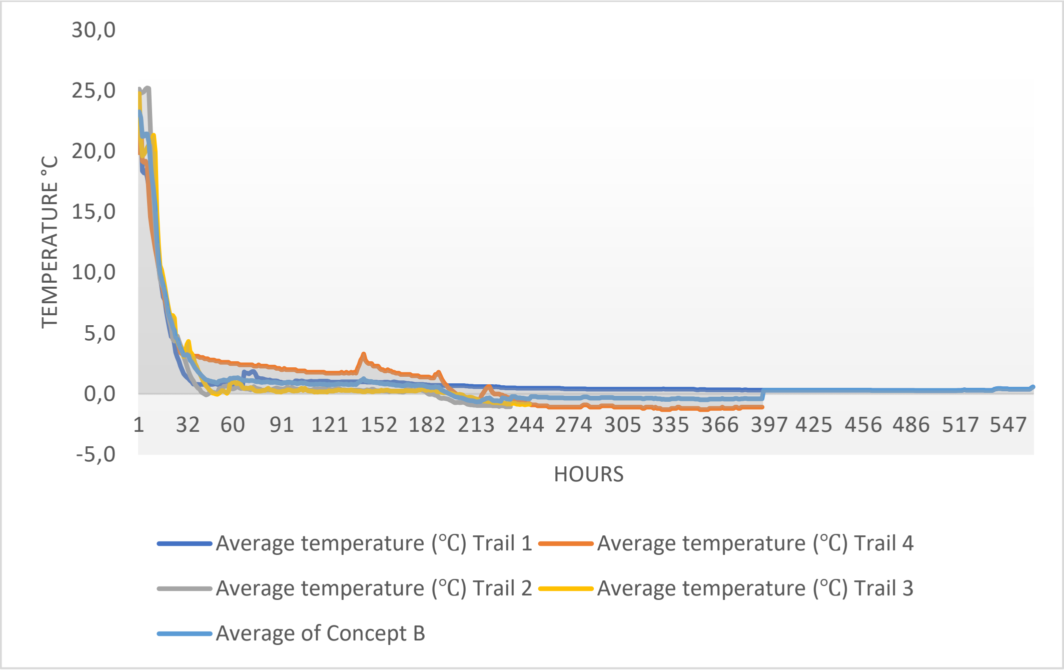


Figure 4.102: Temperature averages of four trials for Concept B

4.7.5.1 Averages of Concept B: Packing and transfer stage

The average time from when the grapes are packed to being placed under forced-air cooling is seven hours and 50 minutes. The current best practice is to place the packed grapes in forced-air cooling within six hours after packing. Figure 4.103 illustrates a line diagram of the temperature averages from the grapes being packed to being placed under forced-air cooling.

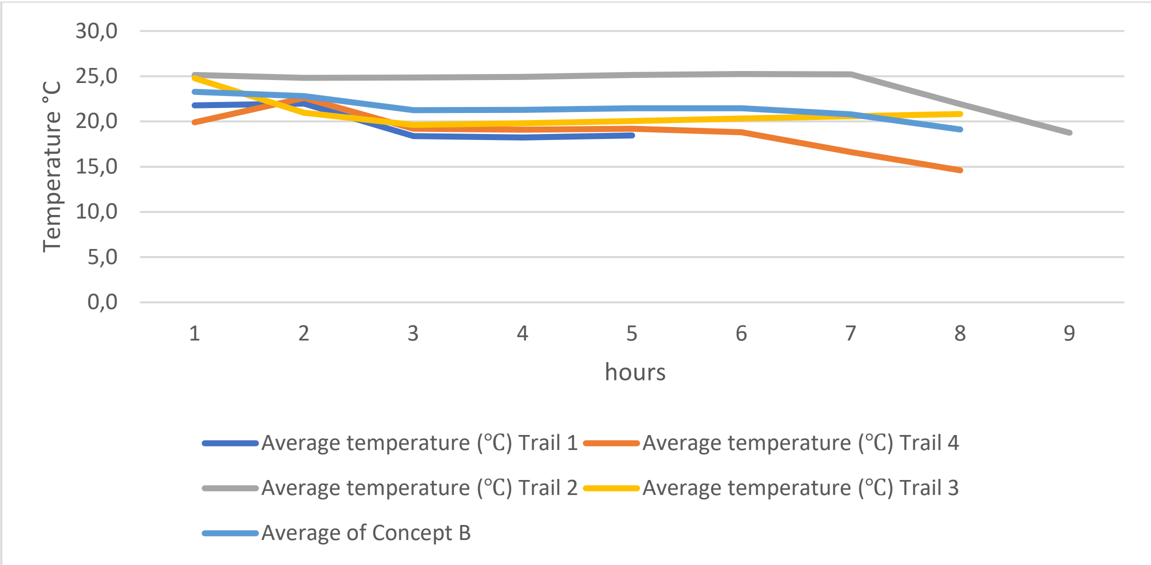


Figure 4.103: Average temperature data from packing to forced-air cooling

Trial 1 was the only trial that met the current best practice of placing grapes under forced-air cooling within six hours after packing, taking five hours for this process. Trials 2 and 3 both experienced temperature increases during the transfer stage.

4.7.5.2 Averages of Concept B: Forced-air cooling stage

No step-down cooling method was used during the forced-air cooling stage of Concept B.

The setpoint of the room was set at -1.5 °C from the start of the forced-air cooling process. The researcher used the average temperature data of all three trials to determine the time taken for Concept A's pulp temperature to reach 10 °C and -0.5 °C. The cluster column illustrated in Figure 4.104 indicates the number of hours it took to reach a pulp temperature of 10 °C during the forced-air cooling stage for Concept B and Figure 4.105 illustrates the cluster column chart to identify the number of hours it took for the pulp temperature to reach -0.5 °C.

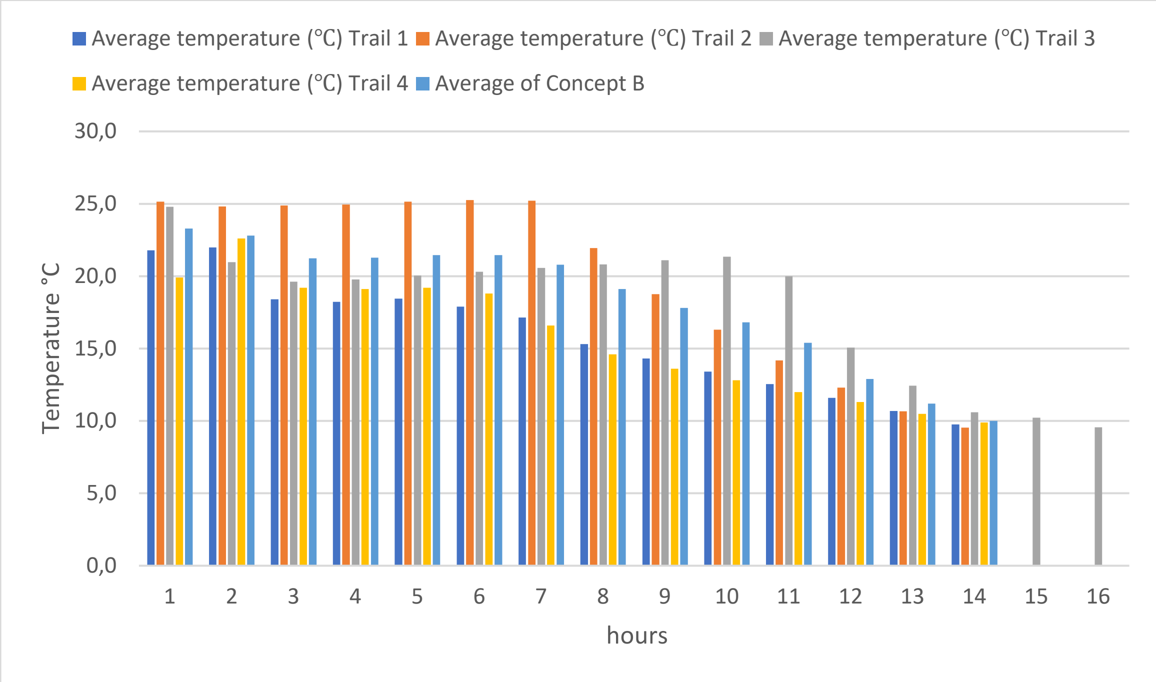


Figure 4.104: Force-cooling stage until 10 °C reached, Concept B

It took 14 hours for the average temperature to reach 10 °C, two hours longer than the current best practice.

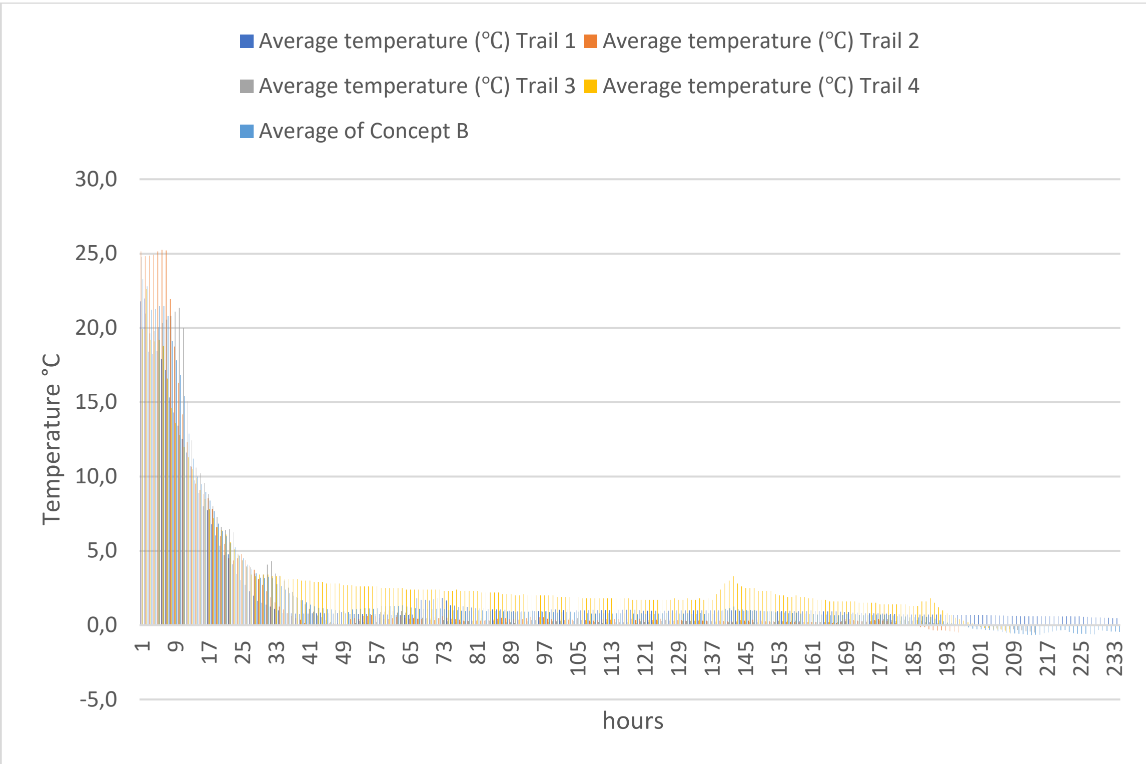


Figure 4.105: Forced-air cooling stage until -0.5 °C reached, Concept B

It took 237 hours for the average temperature to reach -0.5 °C, which was 189 hours longer than the current best practice of 48 hours. Trial 1 never reached -0.5 °C because these pallets were never placed under Steri and a temperature below 1.5 °C is accepted by the PPECB for exporting to Europe. If one looks at the average temperature without taking Trial 1 into consideration, the number of hours it took to get the average temperature below -0.5 °C was 203 hours. This is a very long period and not acceptable, considering that the current best practice is 48 hours. The reason for this length of time to get the fruit to under -0.5 °C is insufficient cooling. The pallets were not cooled through to the core and were moved out of forced-air cooling too early. Stacks moved out caused pallets to be placed under Steri only at a later time. Due to the insufficient cooling and pallets being placed in Steri after a long period, reaching the best practice temperature of -0.5 °C took 203 hours.

4.7.5.3 Averages of Concept B: Steri stage

Trial 1 was not sent to a cold treatment market, and therefore, did not need to comply with the cold treatment protocol. For this stage, Trials 2, 3 and 4 represent the average temperatures. Trial 2 went to Vietnam, Trial 3 to China and Trial 4 to China. The last 24 hours before loading as the Steri stage were used for this comparison, as indicated in Figure 4.106.

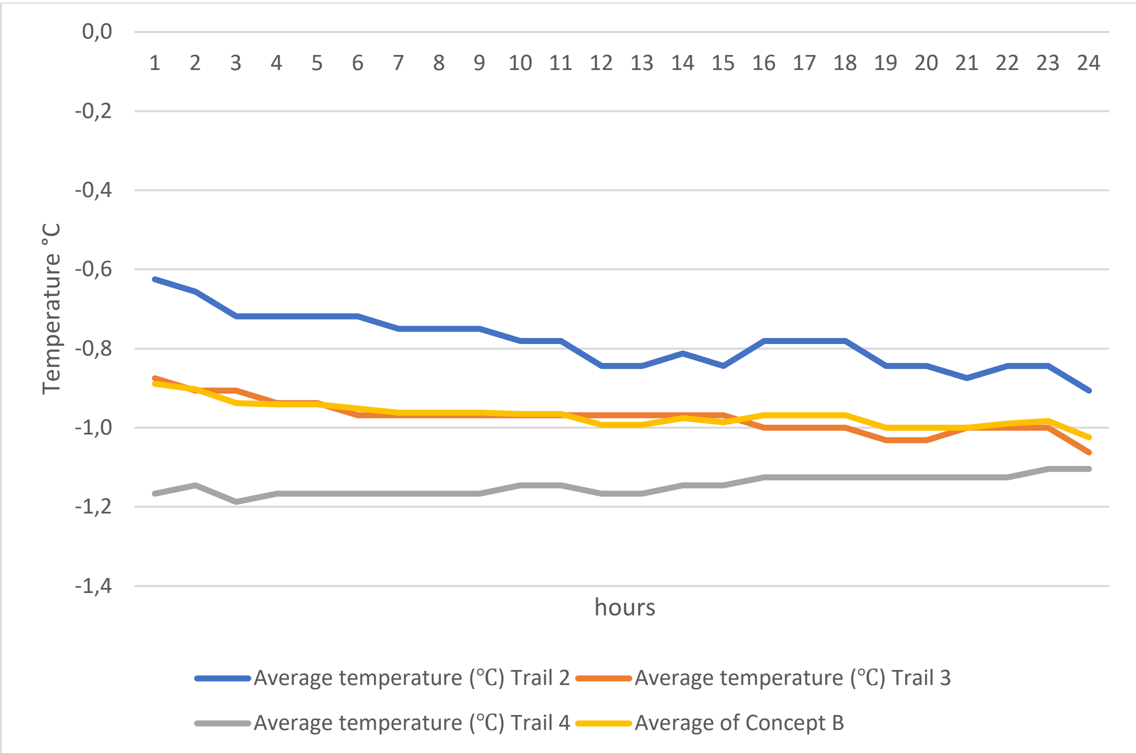


Figure 4.106: Average temperature during the Steri stage, Concept B

The average temperature meets the protocol of being below -0.5 °C and above -1.2 °C.

4.8 Concept C

Two trials were conducted in the Berg River production area to determine the outcome of a cold treatment facility in the same production area. Palletised grapes were loaded directly from Packhouse C to Cold Treatment Facility C.

A total of 24 temperature reading devices were used to conduct the research, divided into two trials.

4.8.1 Concept C, Trial 1

Trial 1 was conducted on pallets destined for Vietnam and 12 devices were divided between three pallets. Pallet ID 060091600235664099 had four devices, namely 5245000; 5244926; 5244990 and 5244917. Pallet ID 060091600235664082 had four devices, namely 5244961, 5244996, 5345030 and 5245006. Pallet ID 060091600235664099 had four devices, namely 5244934, 5244947, 5244958 and 5244968.

The devices were inserted at 08:16 on 16 January 2020 at Packhouse C. Pallets were transferred to Cold Treatment Facility C. At Cold Treatment Facility C the fruit was force-cooled, stored and loaded.

Importer A had an import permit that was issued before 1 December 2019, allowing the fruit to be loaded without going through cold treatment. The fruit could be loaded under 1.5 °C with a PPECB temperature code of GT15. No Steri stage took place due to the permit.

Figure 4.107 illustrates the average temperature data of Concept C, Trial 1.

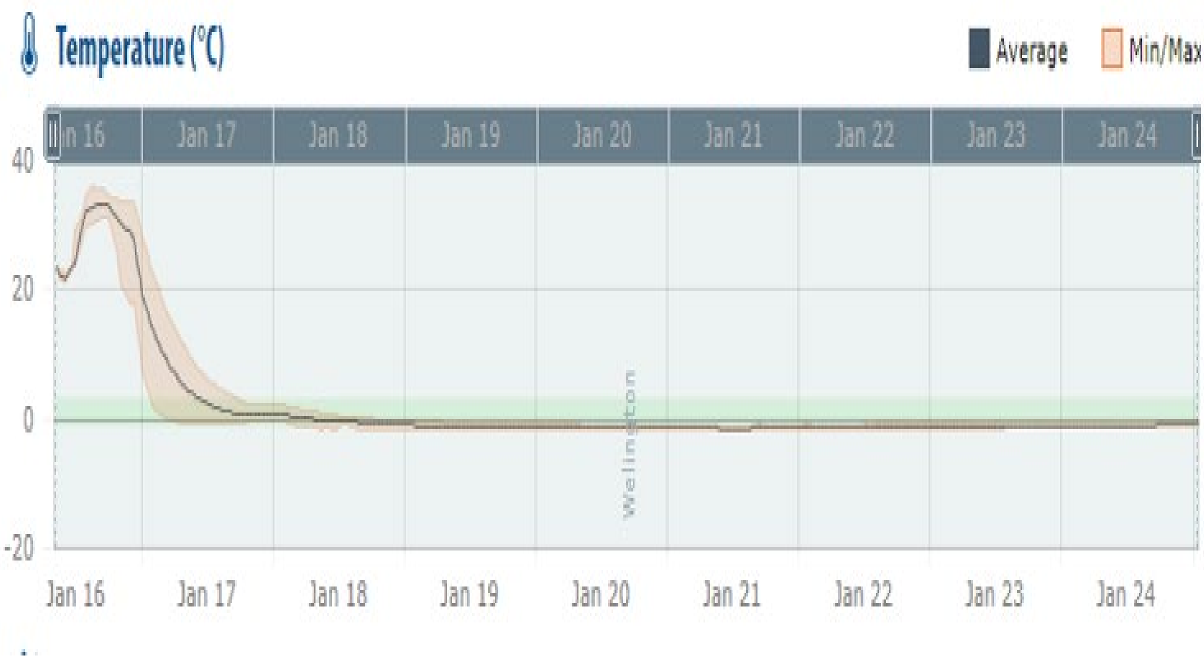


Figure 4.107: Average temperature of Concept C, Trial 1

Figure 4.108 illustrates a line diagram of the temperature data of all 12 devices used in Trial 1 of Concept C.

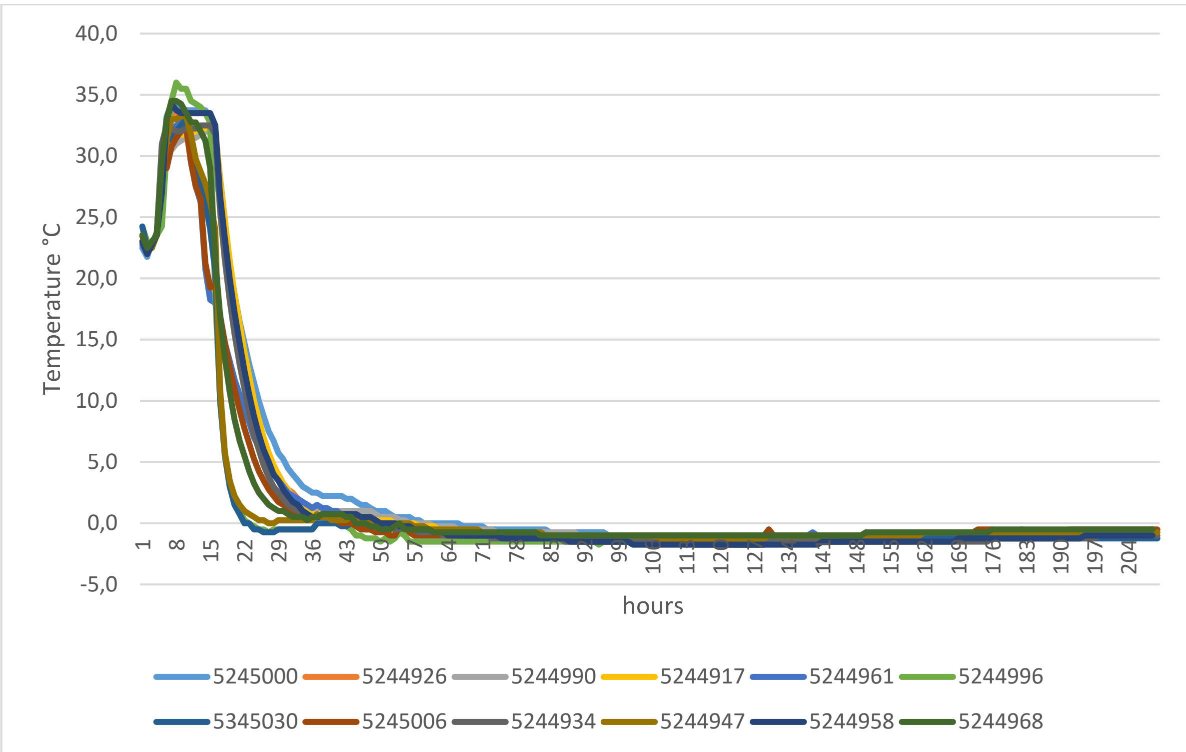


Figure 4.108: The temperature of the 12 devices measured in Concept C, Trial 1

4.8.1.1 Concept C, Trial 1: Packing stage

Sugrathirteen (Midnight Beauty) grapes were packed on 16 January 2020 at Packhouse C. The grapes were packed in B04I cartons, 180 cartons palletised per pallet base.

The devices were inserted at 08:16 while the pallets were palletised, whereafter the pallets were moved to a holding area at the packhouse. Pallets were kept in the holding area until 14:16. The packing and holding stage took approximately six hours before pallets were loaded onto a small flatbed truck.

Figure 4.109 illustrates the temperature data during the packing stage of Concept C, Trial 1.

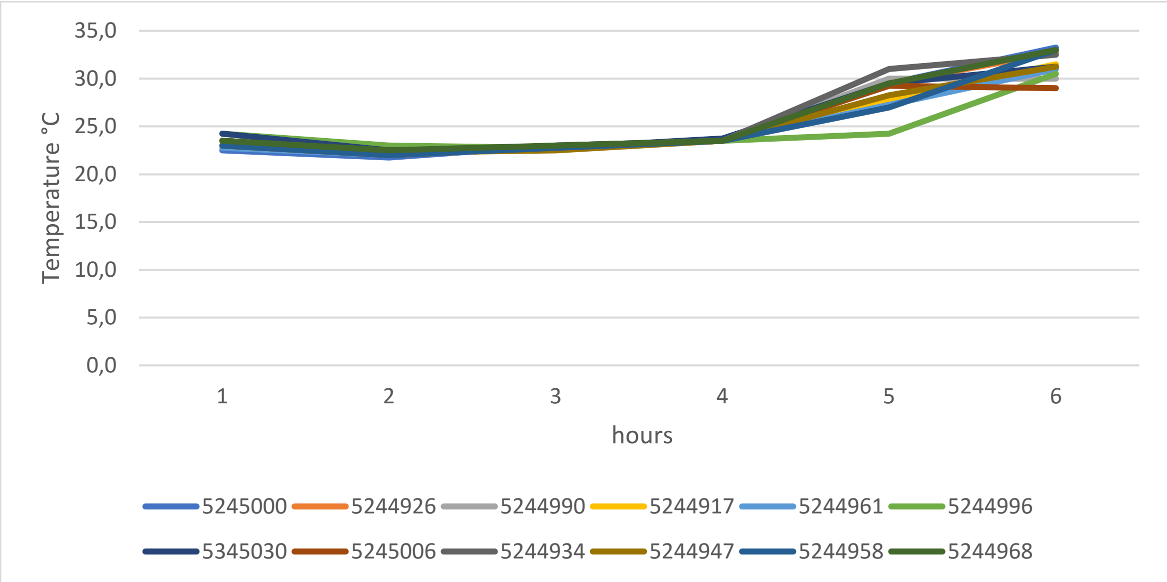


Figure 4.109: Temperature data of the packing stage. Concept C, Trial 1

Temperature breaks were identified by all 12 devices due to the holding area not being under cooling. Figure 4.110 indicates the average temperature of the packing stage of Concept C, Trial 1.

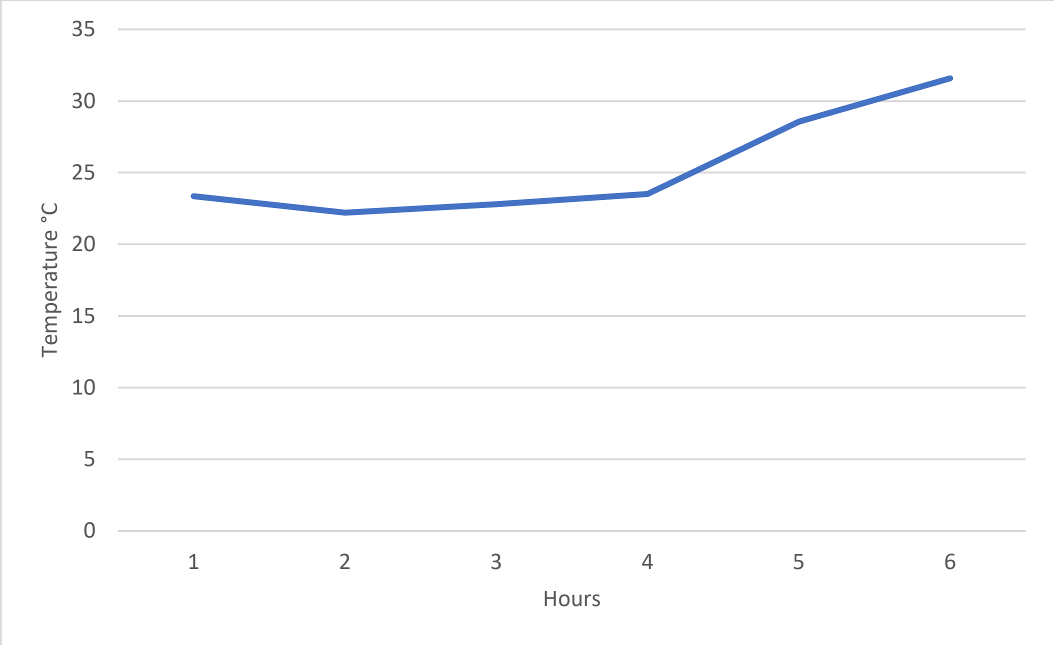


Figure 4.110: Packing stage of Trial 1, Concept C

4.8.1.2 Concept C, Trial 1: Transfer stage

On 16 January 2020 at 14:16 the pallets were loaded onto a flatbed truck and transported to Cold Treatment Facility C.

The transfer stage from Packhouse C to Cold Treatment Facility C took approximately two hours, including the loading and offloading processes, before the pallets were placed under forced-air cooling.

Figure 4.111 illustrates the temperature data of the transfer stage.

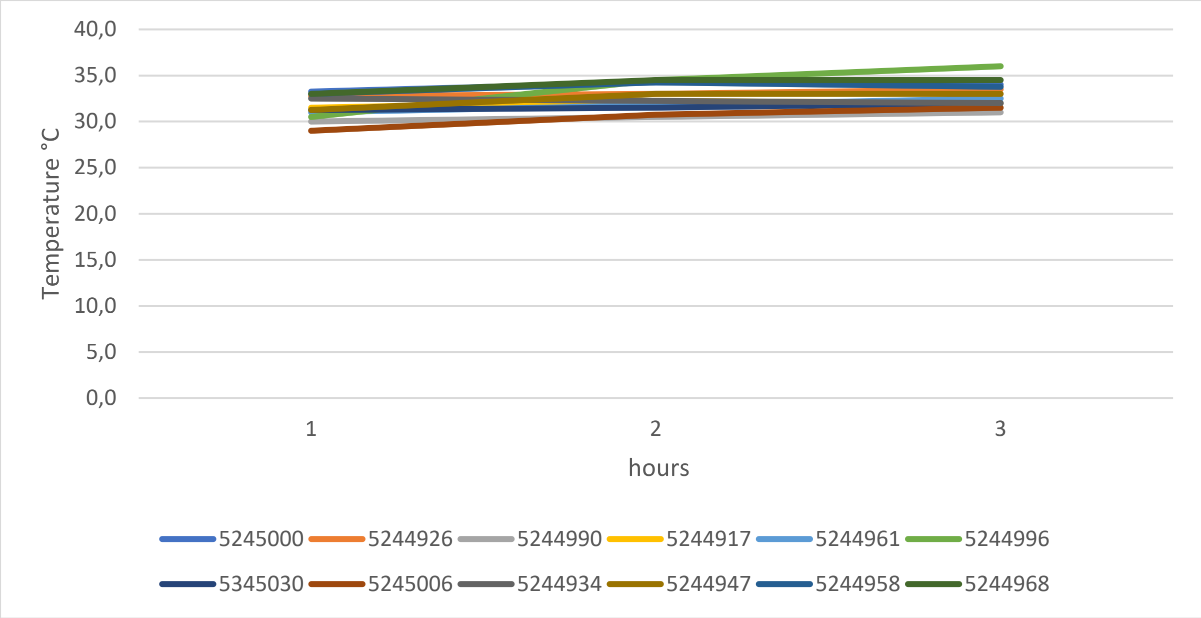


Figure 4.111: Temperature data during the transfer stage. Concept C, Trial 1

All 12 devices indicated temperature breaks, due to being warmer than 2 °C.

4.8.1.3 Concept C, Trial 1: Forced-air cooling stage

Cold Treatment Facility C does not use the step-down cooling procedure but sets the setpoint of the forced-air cooling room to -1.5 °C from the beginning of the forced-air cooling stage.

Figure 4.112 illustrates the temperature data of the first 12 hours of forced-air cooling and Figure 4.113 illustrates the temperature data of the 48 hours of forced-air cooling.

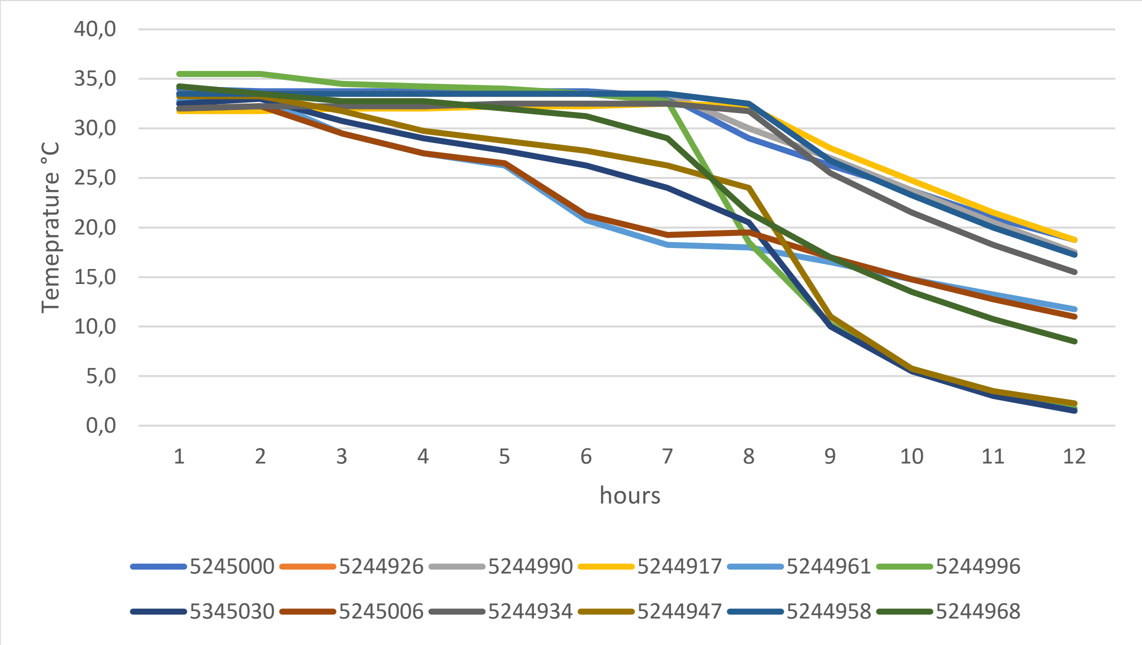


Figure 4.112: First 12 hours of forced-cooling. Concept C, Trial 1

Pallets were placed in forced-air cooling and the process started in the first two hours, but due to Cold Treatment Facility C being in a production area, they must optimise all the space available. Warm pallets were added to the room and the optimum cooling could only start after eight hours. Four devices measured temperatures below 10 °C in 12 hours and the average temperature of all 12 devices was 11.9 °C.

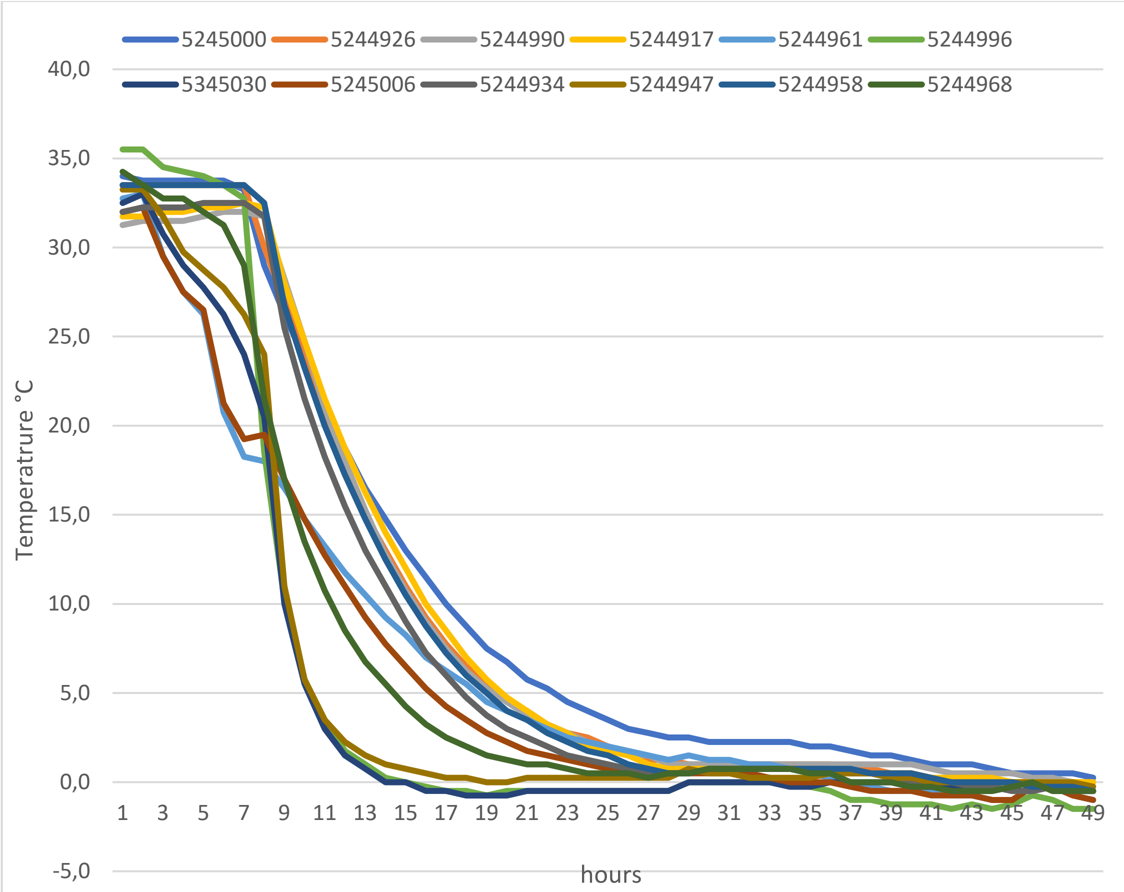


Figure 4.113: Temperature data of the 48 hours forced-air cooling stage. Concept C, Trial 1

All 12 devices indicated temperature breaks due to fruit being warmer than 2 °C until force-air cooling cooled the fruit to under 2 °C. Eight devices measured under -0.5 °C after the 48 hours of forced-air cooling. The average temperature of all 12 devices was -0.5 °C after 48 hours of forced-air cooling.

4.8.1.4 Concept C, Trial 1: Storage stage

Pallets were stored in the forced-air cooling room for 152 hours after the 48 hours of forced-air cooling ended. The pallets were pre-staged on the evening of 24 January 2020 into the pre-staging room. Unfortunately, the receiver was too far from the devices to pick up the data. Therefore, the data for Concept C, Trial 1 ends with the storage stage.

Figure 4.114 illustrates the temperature data of the 152 hours of storage.

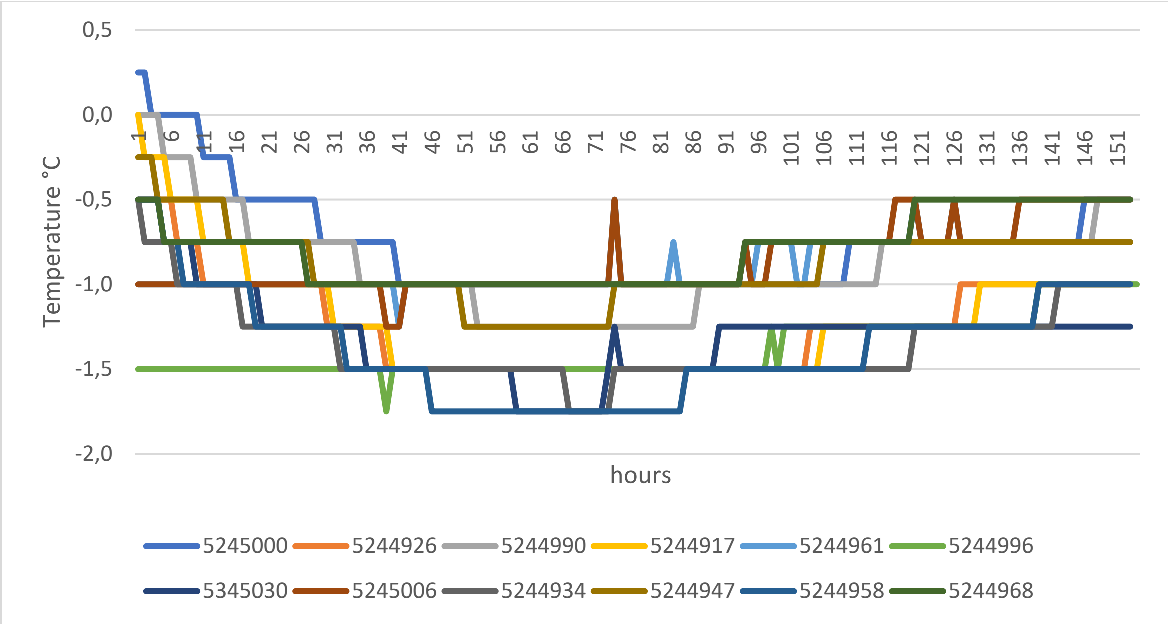


Figure 4.114: Temperature data of the storage stage, Concept C, Trial 1

Five devices indicated temperature breaks by measuring temperatures of -1.5 °C for longer than 90 minutes. Due to the pallet standing in a force-air cooling room for 152 hours set at -1.5 °C and only changed to -1 °C at a later stage, the pulp temperature of the cartons facing outside reached temperatures of -1.5 °C. It is, therefore, ideal to change the setpoint of the room earlier or move the pallets to a holding room if the pallets are not loading to a cold treatment market. The explanation for the temperature fluctuations is that when the forced-air cooling was completed, the setpoint of the room was set to a warmer temperature of -1 °C. There was also movement in the room, for example, pallets being transferred to other rooms or being loaded.

4.8.2 Concept C, Trial 2

Trial 2 was conducted on fruit destined for China. Pallets were packed at Packhouse C and transported to Cold Treatment Facility C. At Cold Treatment Facility C, the fruit was force-cooled, underwent phytosanitary inspection, completed the Steri stage and the loading process took place at the facility. Twelve devices were divided between three pallets, four devices per pallet. Pallet ID 160091600097379190 had four devices, namely 5245001, 5244937, 5244929 and 5345378. Pallet ID 160091600097379206 had four devices, namely 5345069, 5345089, 5244954 and 5244921. Pallet ID 160091600097379213 had four devices, namely 5348084, 5244964, 5345083 and 5244911.

Figure 4.115 illustrates the average temperature data of Concept C, Trial 2.

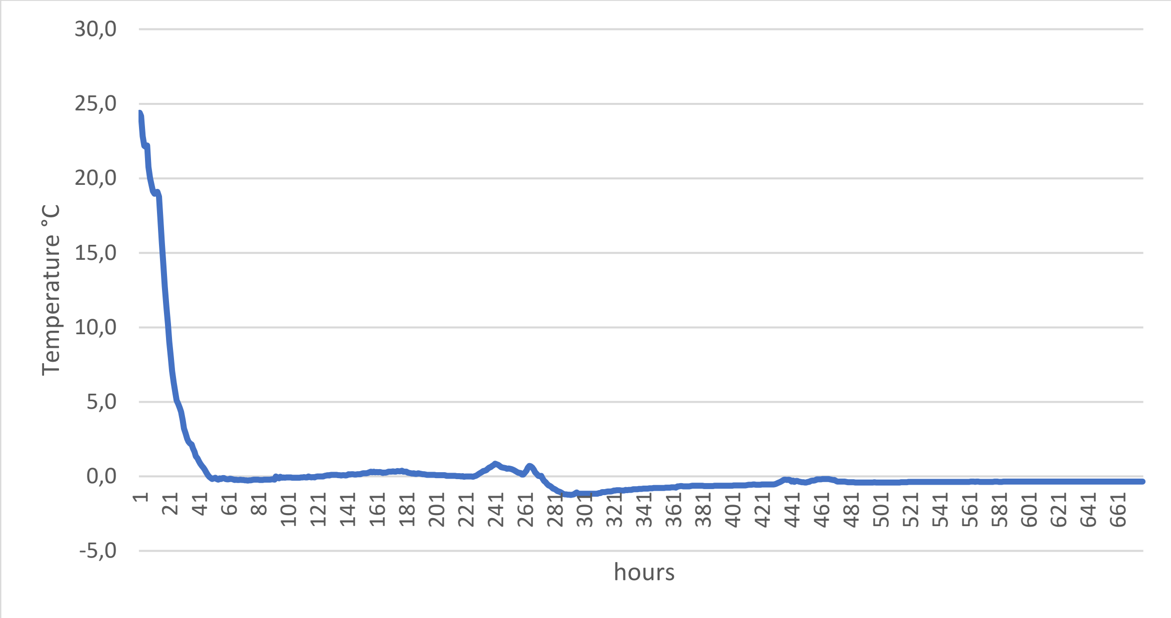


Figure 4.115: Average temperature for Concept C, Trial 2

Figure 4.116 illustrates the temperature data of the 12 devices used in Concept C, Trial 2.

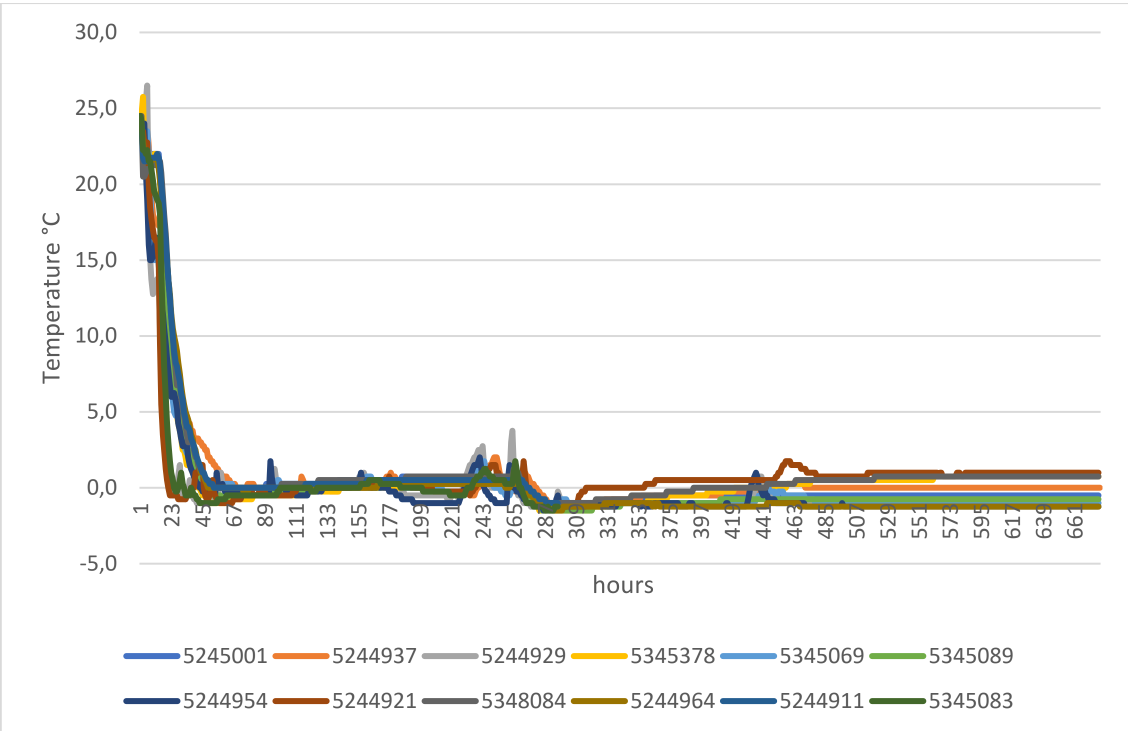


Figure 4.116: Temperature data of Concept C, Trial 2

4.8.2.1 Concept C, Trial 2: Packing stage

Crimson Seedless grapes were packed on 31 January 2020 at Packhouse C. The grapes were packed in B04I cartons, 180 cartons palletised per pallet.

The devices were inserted at 08:55 while the pallets were palletised. The pallets were kept in a holding area for five hours until being loaded onto a small flatbed truck.

Figure 4.117 illustrates the temperature data during the packing stage.

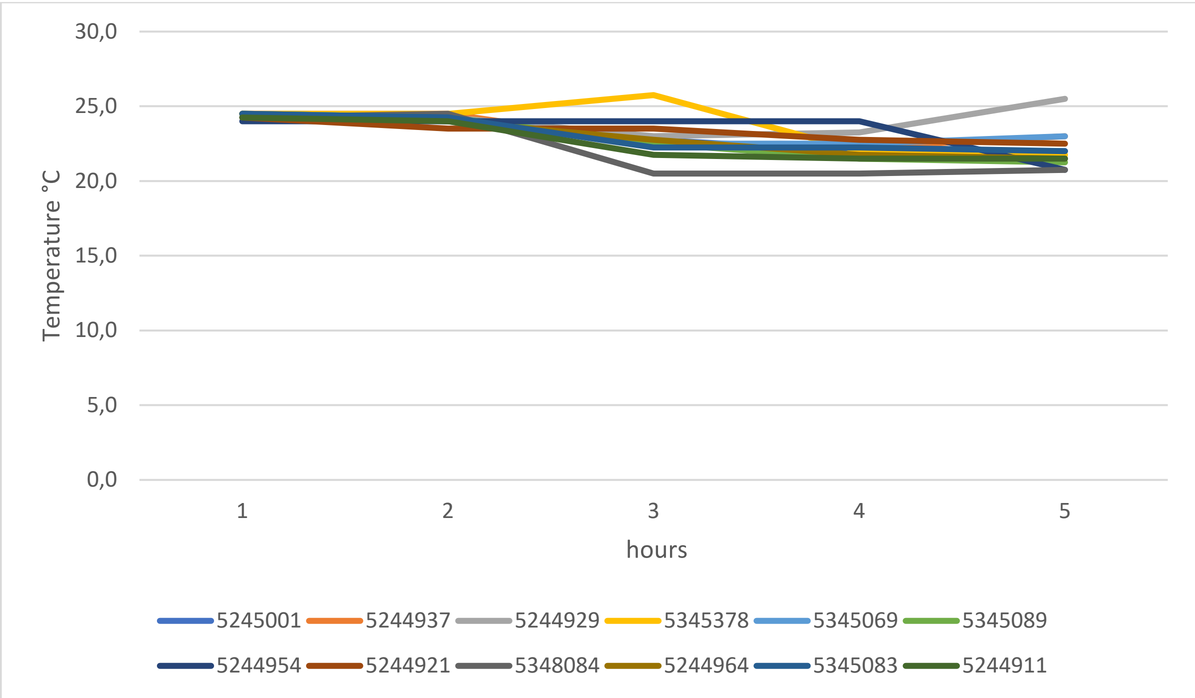


Figure 4.117: Temperature data of the packing stage of Concept C, Trial 2

All the devices indicated a temperature break by measuring temperatures warmer than 2 °C. Device 5244929 indicated a temperature increase during the packing and transfer stage.

4.8.2.2 Concept C, Trial 2: Transfer stage

For Concept C, Trial 2, the transfer stage took three hours. This time included the loading and offloading processes before the pallets were placed into a forced-air cooling tunnel.

Figure 4.118 indicates the temperature data of the transfer stage.

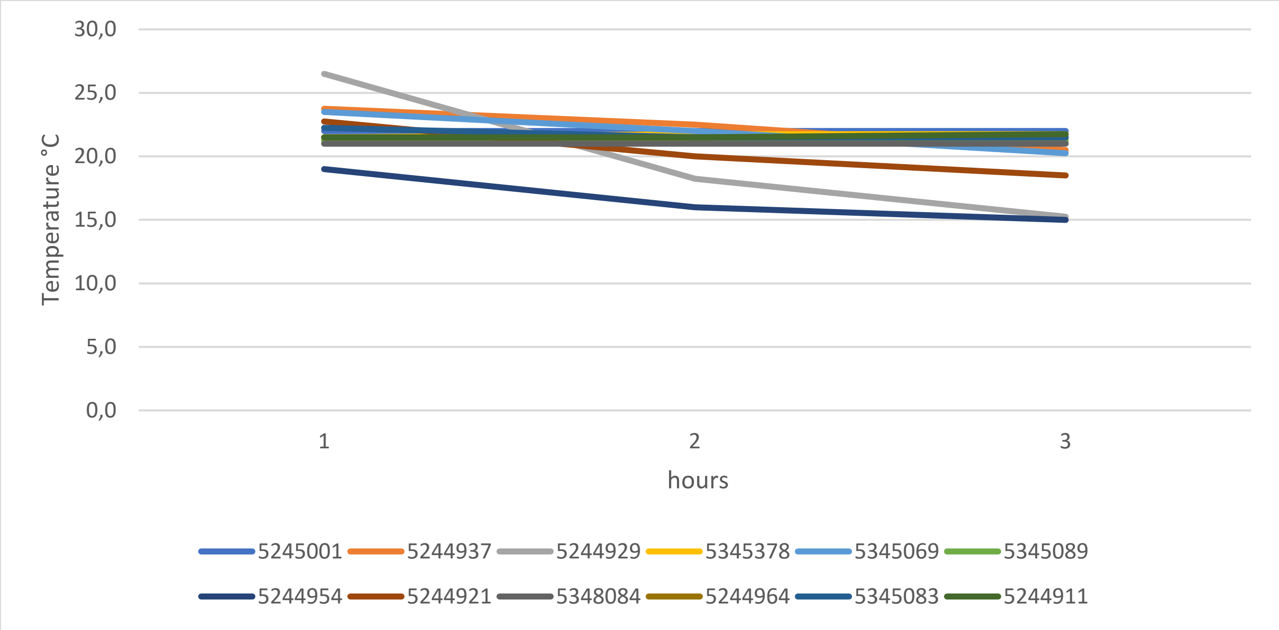


Figure 4.118: Temperature data of the transfer stage, Concept C, Trial 2

All the devices indicated temperature breaks until the fruit were force-air cooled to under 2 °C. When offloading the flatbed trucks under a shaded area, the temperature of the devices on the outside cartons of the pallets decreased rapidly.

4.8.2.3 Concept C, Trial 2: Forced-air cooling stage

Cold Treatment Facility C does not use the step-down cooling procedure. It sets the setpoint of the forced-air cooling room to -1.5 °C from the beginning of the forced-air cooling stage.

Figure 4.119 indicates the temperature data over 12 hours under forced-air cooling.

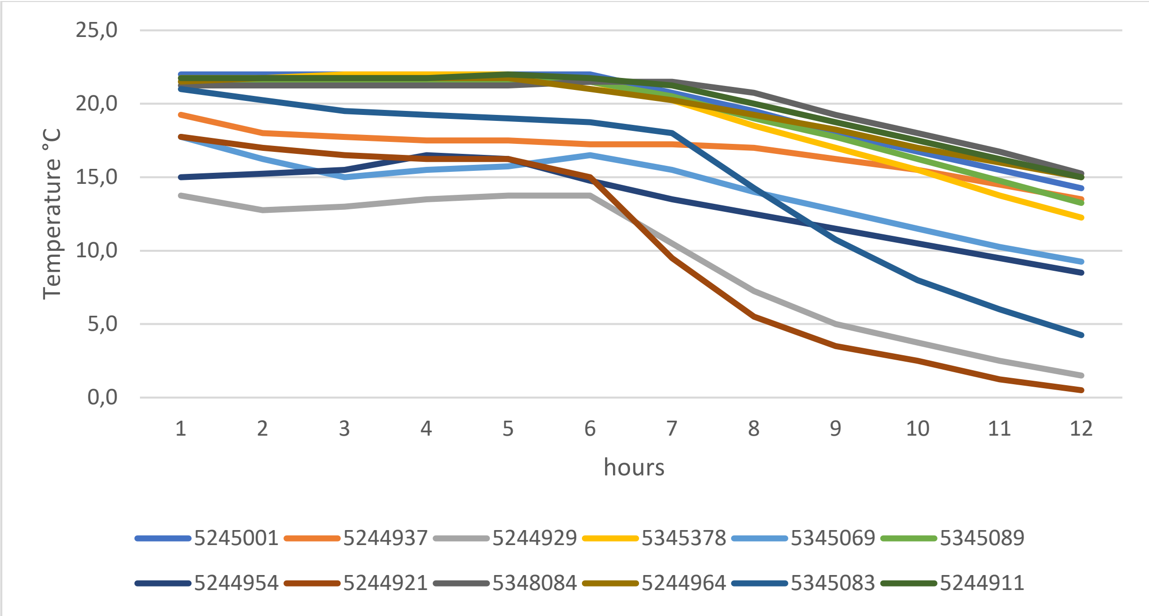


Figure 4.119: Temperature data of the first 12 hours of force-cooling. Concept C, Trial 2

All the devices indicated temperature breaks. In addition, three devices indicated an increase in temperature due to warm pallets being added to the tunnel. After 12 hours of forced-air cooling, five devices were below 10 °C with the average of the devices being 10.2 °C.

Figure 4.120 indicates the temperature data over 48 hours under forced-air cooling.

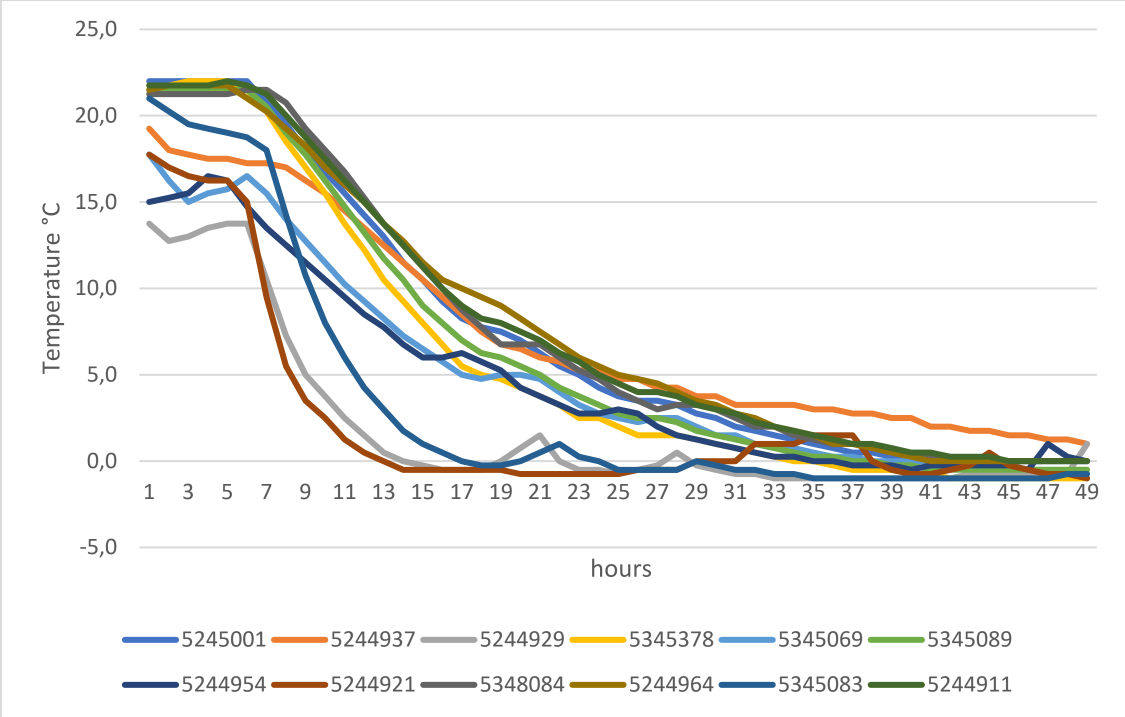


Figure 4.120: Temperature data of the 48-hour forced-air cooling stage. Concept C, Trial 2

All 12 devices indicated temperature breaks until the pulp temperature decreased below 2 °C during the force cooling stage. The average temperature break lasted 29 hours. Temperature increases did occur due to samples being pulled while pallets were in the forced-air cooling tunnels. Four devices measured temperatures below -0.5 °C after the 48 hours of forced-air cooling. The average temperature was -0.1 °C.

4.8.2.4 Concept C, Trial 2: Inspection and storage stage

The phytosanitary inspection was conducted while the pallets were standing in the forced-air cooling tunnels. After 48 hours of forced-air cooling, the pallets remained in the tunnel but the suction fans of the tunnels were switched off, transforming the forced-air cooling room into a holding room. This reduces the handling of the pallets and the risk for temperature breaks to occur. The pallets were stored for 215 days before the Steri stage began. The delay was caused by the Covid-19 pandemic. The schedules of vessels changed, causing fewer shipping lines to ship to the Far East markets.

Figure 4.121 illustrates the temperature data of the storage stage for Concept C, Trial 2.

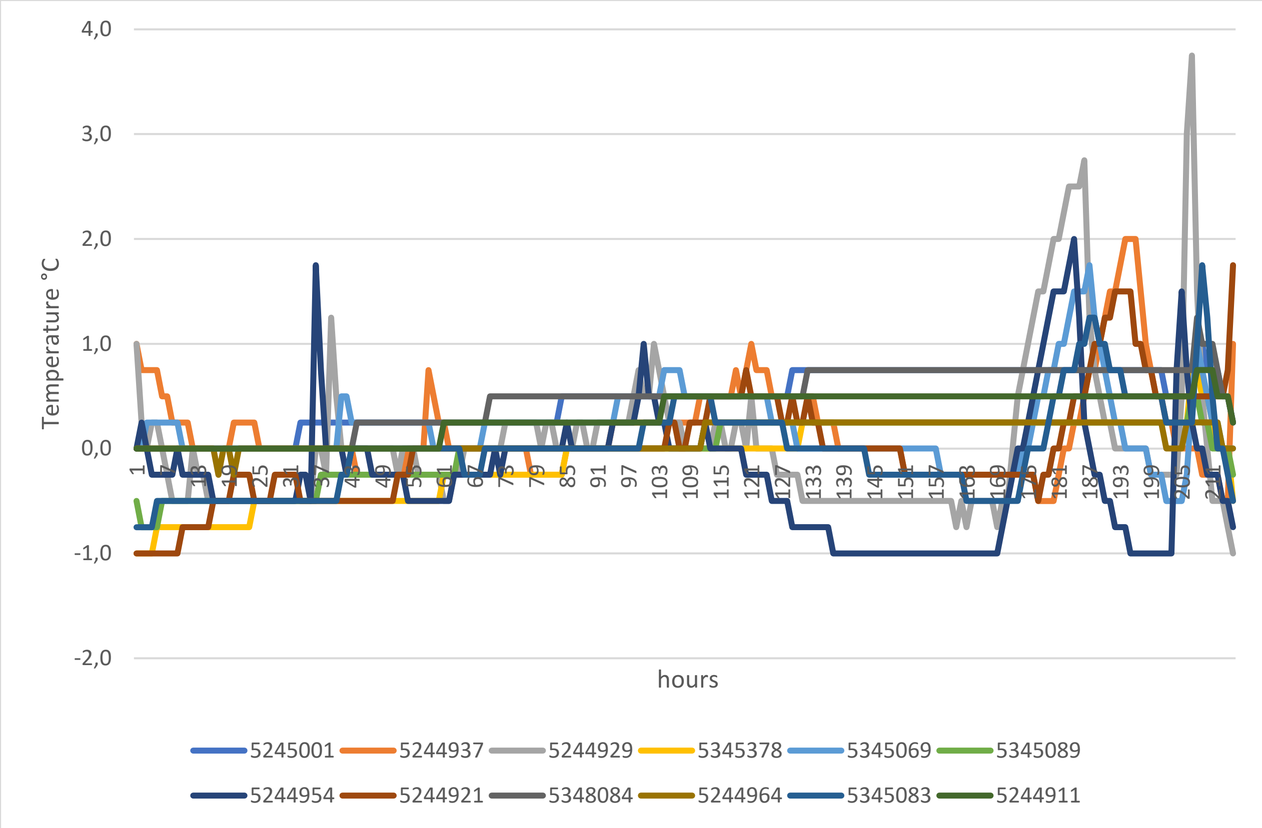


Figure 4.121: Temperature data of the storage stage for Concept C, Trial 2

One temperature break was identified in the temperature data of device 5244929. Temperature spikes were identified in two devices. The reason for the temperature spikes and break can be ascribed to switching the room off while working inside the room and by placing the sample cartons back and re-palletizing the pallets. Movement of pallets inside the room will also influence the temperature.

4.8.2.5 Concept C, Trial 2: Steri stage

Pallets were packed and passed for China. The protocol for China states that the fruit must be in Steri for a minimum of 24 hours and in the last six hours the pulp temperature must be between -0.5 °C and -1.2 °C. Figure 4.122 indicates the temperature data of the 24-hour Steri stage and Figure 4.123 indicates the last six hours of the Steri stage.

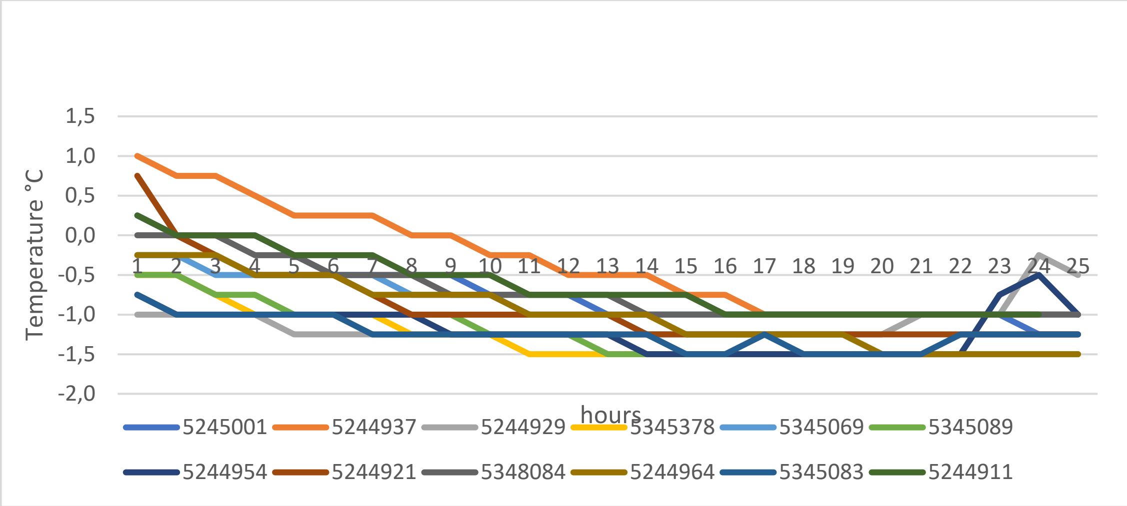


Figure 4.122: Temperature data during the Steri stage of Concept C, Trial 2

Three temperature breaks were indicated by measuring a temperature of -1.5 °C and one temperature spike occurred by measuring a temperature of -1.5 °C for 60 minutes.

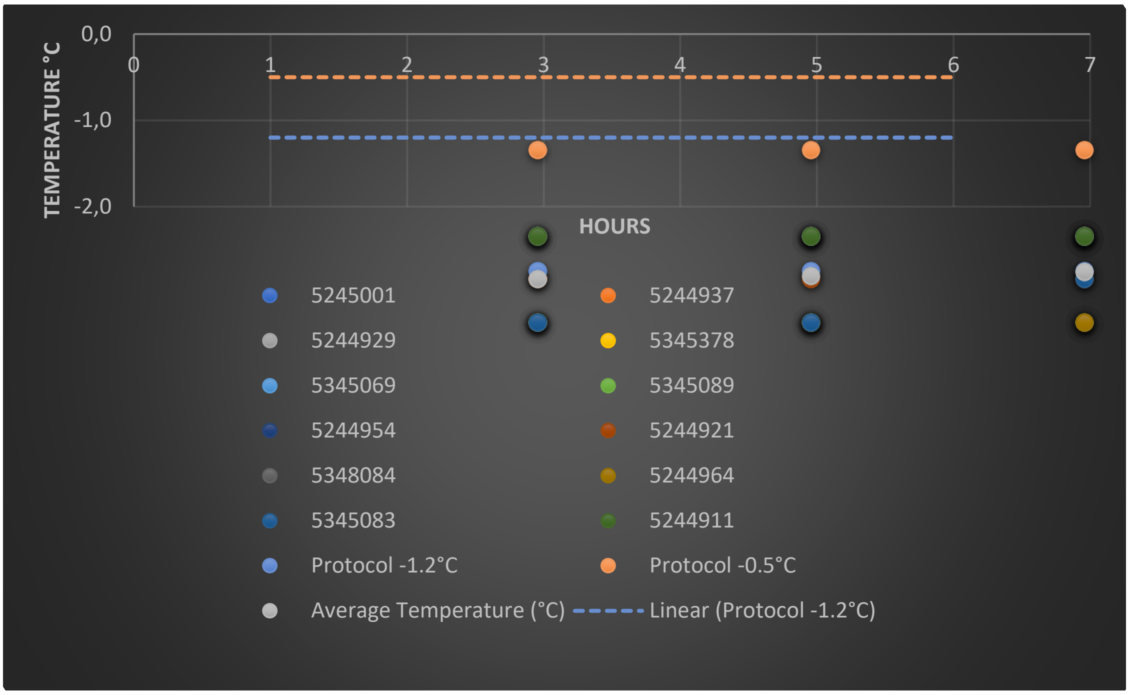


Figure 4.123: Last six hours of the Steri stage of Concept C, Trial 2

Four devices were within protocol, being between -0.5 °C and -1.2 °C for the last six hours of the Steri stage. Seven devices were colder than -1.2 °C, with four of the seven devices indicating temperature breaks and one device a temperature spike by measuring temperatures below -1.5 °C

4.8.2.6 Concept C, Trial 2: Loading stage

The loading process started at 11:30 and finished at 12:03 on 12 February 2020. Pallets were loaded into container number DFOU6157819.

4.8.2.7 Concept C, Trial 2: Stacking and shipping stage

The container was transported from Cold Treatment Facility C to the stack in the Port of Cape Town. The container arrived at the stack on 12 February 2020 and was monitored in the stack for two days until it was loaded onto the vessel on 14 February 2020. The transit time from Cape Town to Hong Kong was 21 days. Unfortunately, the researcher only retrieved temperature data of 380 hours after the loading stage.

Figure 4.124 illustrates the 380 hours of temperature data during the shipping stage. Device 5244911 only supplied temperature data until the pallets were loaded into the container.

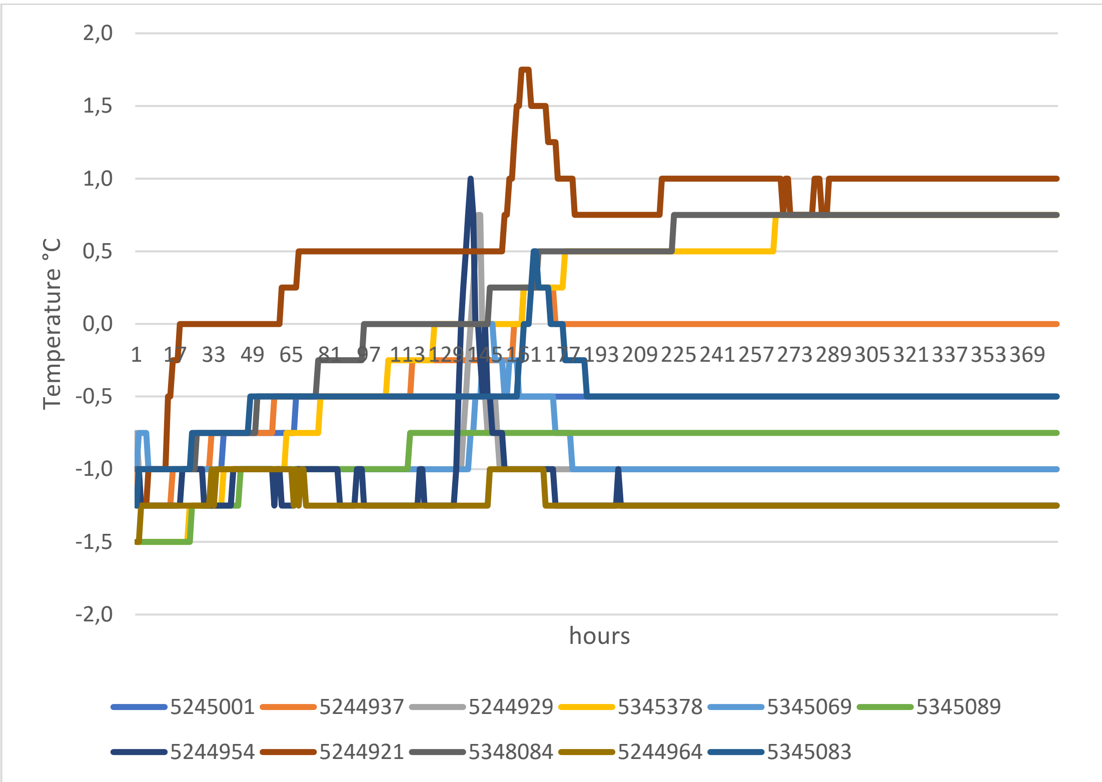


Figure 4.124: Temperature data of the shipping stage. Concept C, Trial 2

The container setpoint was set at -1 °C, and therefore, the pulp temperature will increase proportionately to the increase in air temperature.

One temperature break was identified in the start of the stage. Of the 11 devices, 10 indicated an increase in temperature and temperature fluctuations were identified.

4.8.3 Averages of Concept C

The averages of each trial supply a holistic view of Concept C.

Figure 4.125 illustrates the average temperature data of both trials of Concept C.

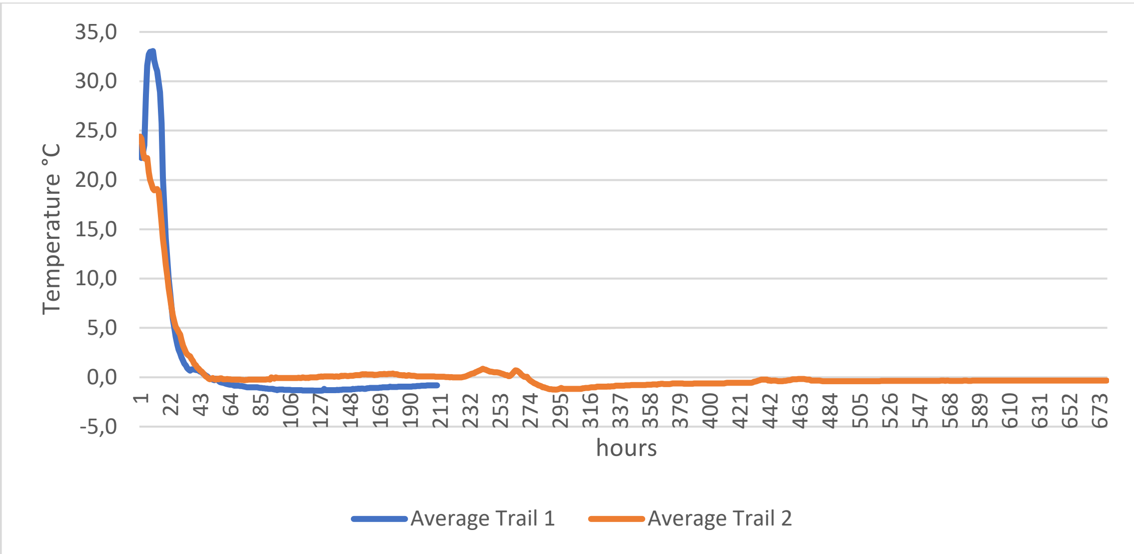


Figure 4.125: Temperature averages of Concept C

4.8.3.1 Averages of Concept C: Packing and transfer stage

The average time from when the grapes were packed to being placed under forced-air cooling was eight hours. The current best practice is to place the packed grapes in forced-air cooling within six hours after packing.

Figure 4.126 illustrates the temperature averages from the grapes being packed to being placed under forced-air cooling.

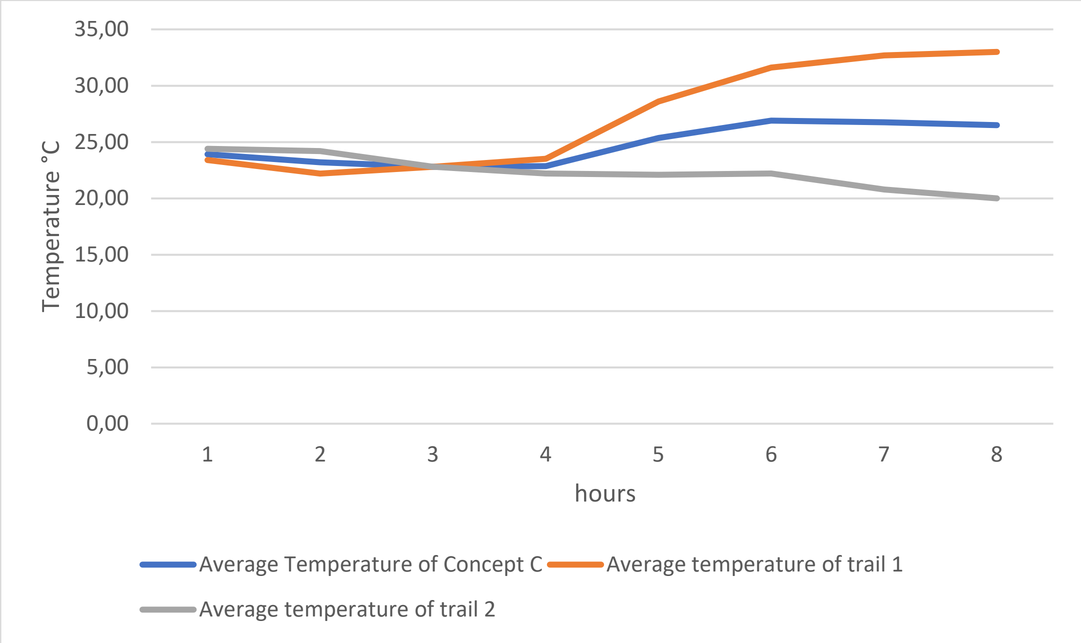


Figure 4.126: Average temperature during the packing and transfer stage of Concept C

A clear increase and temperature break was identified by Trial 1, causing the average temperature of Concept C to indicate a temperature break.

4.8.3.2 Averages of Concept C: Forced-air cooling stage

The current best practice is to get fruit to under 10 °C within 12 hours and below -0.5 °C in 48 hours. The researcher used the average temperature data of the two trials to determine the time taken for Concept C's pulp temperature to reach 10 °C and -0.5 °C.

Figure 4.127 indicates the number of hours it took to reach a pulp temperature of 10 °C during the forced-air cooling stage for Concept C.

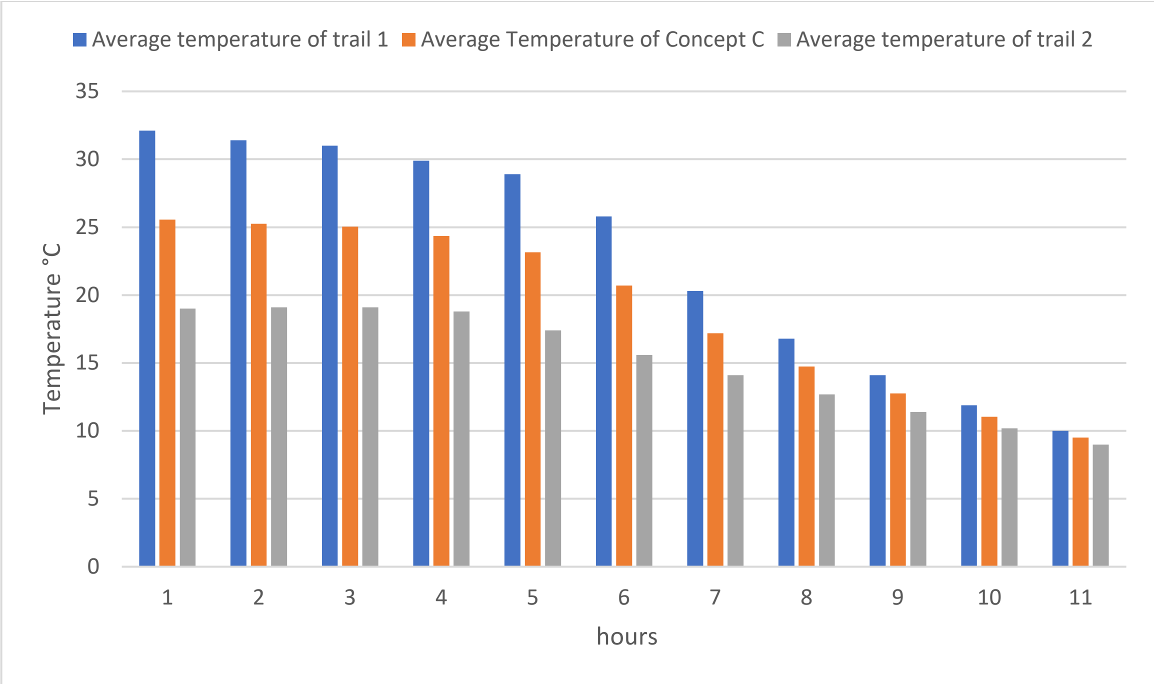


Figure 4.127: Average temperature data of Concept C until pulp reached 10 °C

The average time it took the pulp temperature to reach 10 °C was 11 hours, one hour faster than the current best practice.

Figure 4.128 illustrates the number of hours it took for the pulp temperature to reach -0.5 °C.

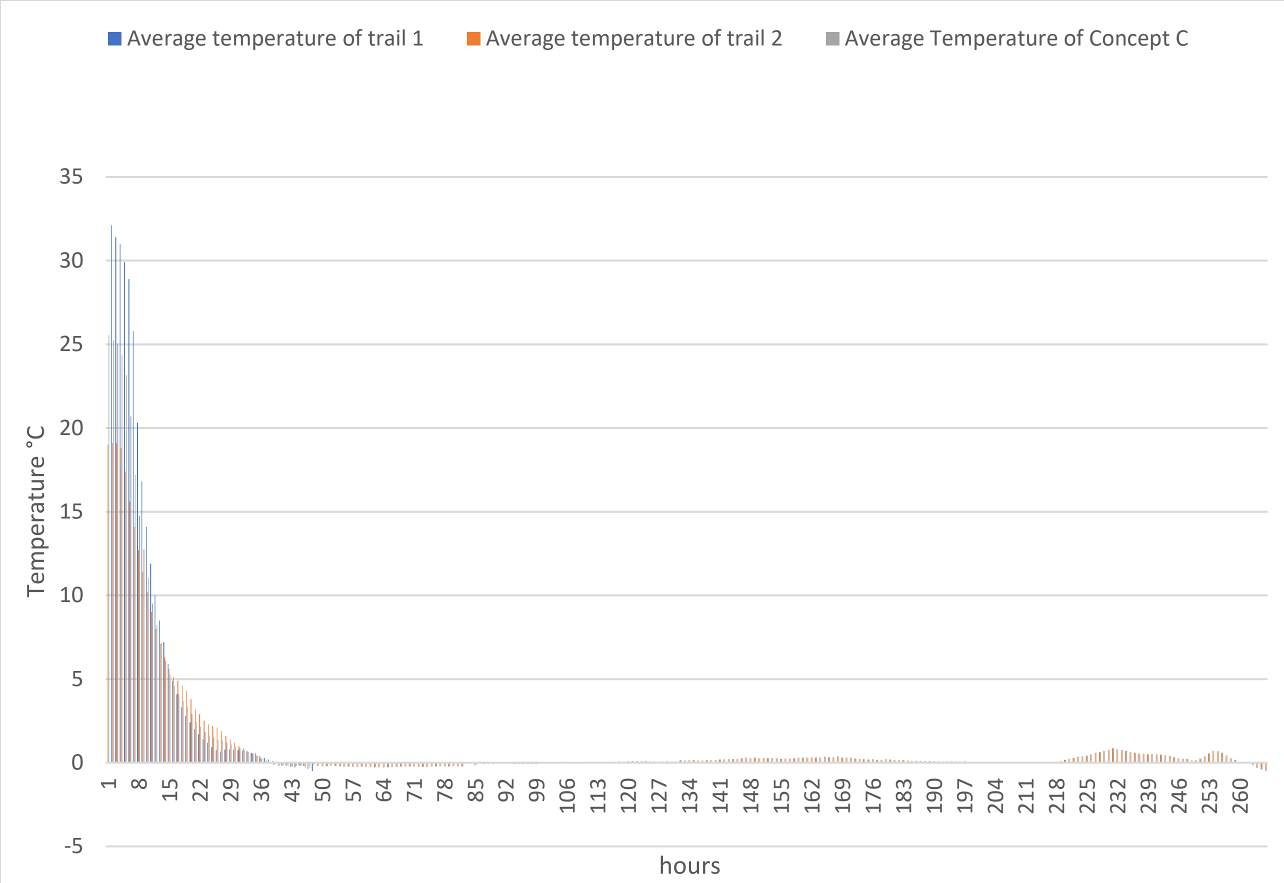


Figure 4.128: Average temperature data of Concept C until pulp reached -0.5 °C

The average temperature of Trial 1 took 47 hours to reach -0.5 °C, one hour faster than the current best practice. Trial 2's average temperature only reached -0.5 °C in the Steri stage and it took 266 hours due to a long storage period before the Steri stage started. After 48 hours, the average temperature of Trial 2 was -0.3 °C.

4.8.3.3 Averages of Concept C: Steri stage

Trial 1 did not enter the Steri stage, and therefore, no comparison can be made between the two trial averages.

4.9 Temperature breaks of all three Concepts

It is important to look at the temperature breaks and the duration of the breaks to determine if the breaks can be avoided and which concept will be the more preferred concept used to maintain the cold chain integrity.

Table 4.12 illustrates all the temperature breaks identified throughout the stages of the three trials of concept A.

Table 4.12 Temperature breaks identified in Concept A

Device numbers	Temperature break duration, measured in hours, from the packing, transfer, forced- air cooling and storage stage. Temperature measured 2 °C and above.	Temperature break duration, measured in hours, from the Steri , loading and shipping stage. Temperature measured -1.5 °C and below for more than 90 minutes.	
5222595	43	14	Trial 1, Concept A
5222627	52	6	
5222677	57		
5345344	68		
5222616	61		
5222667	40	15	
5222590	54	5	
5222586	62		
5222631	63		
5345308	57		
5244916	60	103	Trial 2, Concept A
5244915	63		
5345004	75		
5244981	65	5	
5244942	63	31	
5244941	50	35	
5345081	65		
5345082	69	10	
5345339	80		
5345091	52	60	
5345019	63	71	
5244994	56	104	
5345358	80	31	Trial 3, Concept A
5345335	56		
5345379	52	44	
5345376	53		
5345383	65	32	
5244971	66	36	
5345362	56	23	
5245002	62		
5345310	80	38	
5345074	56	91	
5345072	62		
5345009	57	24	
Average Hours	**60,7**	**38,9**	

All 34 devices indicated temperature breaks from the packing stage until the fruit were forced-air cooled to under 2 °C. The fruit were cooled from temperatures measured between 18 °C and 25,3 °C to the desired temperature. An increase in temperature took place and this process can be classified as successful. The current best practises were created to reduce the packing temperature of the fruit pulp to increase the shelf life of the product. The current best practises are to get the fruit under forced-air cooling within six hours after packing, to cool the fruit below 10 °C within 12 hours of forced-air cooling and to cool the fruit to -0.5 °C within 48 hours.

For Concept, A the cold storage facility used the step-down cooling method. This new cooling method does not comply with all the current best practises, as it takes longer for the fruit pulp temperature to reach the desired temperatures. It took an average of 61 hours and 10 minutes for the pulp temperature to measure below 2 °C.

The temperature breaks identified from the Steri stage to when the fruit were shipped, were identified in 20 of the 34 devices. All the breaks were because of temperatures measuring -1.5 °C and below. Average hours that the 20 devices measured -1.5 °C and below were 39 hours and 30 minutes. This is a big concern as the fruit went too cold for a long period. Shipping lines and PPECB inspectors request temperatures of -1 °C to reduce the risk of probe failure in the container, due to temperature increase from the forced-air cooling tunnel to the container. The PPECB protocols also state that the supply air of the tunnels can go up to -1.5 °C. With the new technology and pressure to reach temperatures of -1 °C, cold treatment facilities run the forced-air cooling for too long period on a setpoint of -1.5 °C. The cold treatment breaks of -1.5 °C and colder can be avoided by better cold chain management.

The temperature breaks of Concept B are illustrated in Table 4.13.

Table 4.13 The temperature breaks identified in Concept B

Device numbers	Temperature break duration, measured in hours, from the packing, transfer, forced- air cooling and storage stage. Temperature measured 2 °C and above.	Temperature break duration, measured in hours, from the forced- air cooling and storage stage. Temperature measured -1.5 °C and below for more than 90 minutes.	Temperature break duration, measured in hours, from the Steri , loading and shipping stage. Temperature measured -1.5 ℃ and below for more than 90 minutes.	
5345035	20	9		Trial 1, Concept B
5244970	22			
5345077	22			
5345340	57			
5244985	30			
5245008	35			
5244998	141			
5345309	170			
5345380	89			
5345092	28			
5244957	32			
5244913	18			
5244943	33			Trial 2, Concept B
5244956	41			
5244922	46			
5345090	33			
5244924	44			
5345299	26			
5345000	39			
5345088	41			
5244980	32			Trial 3, Concept B
5244972	32			
5345042	26			
5244952	32			
5244920	36			
5345049	30			
5244939	30		24	
5345067	32			
5345013	191			Trial 4, Concept B
5245004	47		167	
5244983	19			
5244982	191			
5244960	18			
5245003	24			
5345031	37			

5244986	191			
5345093	57			
5244988	25			
5244944	192			
5244936	198			
Average Hours	**60,2**	**9,0**	**95,5**	

All 40 devices indicated temperature breaks from the packing stage until the fruit were forced-air cooled to under 2 °C. The cold storage facility in Concept B used the more frequently used forced-air cooling method by setting the setpoint to -1.5 °C from the start of the process and removing the fruit out of the force-air cooling tunnels, after 48 hours and placing them in holding rooms. It took an average of 60 hours and 20 minutes for the pulp temperature to measure below 2 °C. Irregular temperatures were measured with this cooling method, one device indicated a temperature break of measuring -1.5 °C and colder during the forced-air cooling method and eight devices were above 2 °C when they were removed from the forced-air cooling tunnels and stored in the holding rooms. Not all the pallets were cooled to the desired temperatures and the tautliner used to transport the pallets from the cold storage facilities to the cold treatment facilities should not be used for transporting temperature sensitive products.

The temperature breaks identified from the Steri stage to when the fruit were shipped, were identified in two of the 40 devices and lasted for 95 hours and 50 minutes. All the breaks were because of temperatures measuring -1.5 °C and below. The cold treatment breaks of -1.5 °C and colder can be avoided by better cold chain management.

The temperature breaks of Concept C are illustrated in Table 4.14.

Table 4.14: Temperature breaks of Concept C

Device numbers	Temperature break duration, measured in hours, from the packing, transfer, forced- air cooling and storage stage. Temperature measured 2 °C and above.	Temperature break duration, measured in hours, from the forced- air cooling and storage stage. Temperature measured -1.5 °C and below for more than 90 minutes.	Temperature break duration, measured in hours, from the Steri , loading and shipping stage. Temperature measured -1.5 °C and below for more than 90 minutes.	
5245000	44			Trial 1, Concept C
5244926	33	65		
5244990	33			
5244917	32	65		
5244961	33			
5244996	19	98		
5345030	19	54		
5245006	28			
5244934	30	88		
5244947	20			
5244958	31	80		
5244968	26			
5245001	39			Trial 2, Concept C
5244937	50			
5244929	19			
5345378	33		37	
5345069	37			
5345089	36		36	
5244954	35		9	
5244921	18			
5348084	41			
5244964	41		8	
5345083	21			
5244911	36		5	
Average Hours	**31,4**	**75,0**	**19,0**	

All 24 devices indicated temperature breaks from the packing stage until the fruit were forced-air cooled to under 2 °C. The cold storage facility in Concept C used the more frequently used forced-air cooling method by setting the setpoint to -1.5 °C from the start of the process and removing the fruit out of the force-air cooling tunnels, after 48 hours and placing them in holding rooms. It took an average of 31 hours and 40 minutes for the pulp temperature to measure below 2 °C. Trial 1 of Concept C was left in the force-air cooling tunnel for a long period before the pallets were moved to the holding rooms, causing six devices to measure temperature of -1.5 °C and colder for a duration of 75 hours. Trial 1 of Concept C were not place under Steri, and therefore, there are no readings under the Steri stage.

The temperature breaks identified from the Steri stage to when the fruit were shipped, were identified in five devices. All the breaks were temperatures measuring -1.5 °C and below.

4.10 Conclusion

During the research, the current best practises and the norm were challenged by cooling methods such as the step-down cooling method and the breaching experiment, Concept A.

Temperature breaks during the packing and the first part of forced-air cooling stage, will always occur due to the field heat that must be removed from fruit. During the packing process field heat are removed to a desired temperature of 18 °C, the forced-air cooling method removes all the warm heat and cools the fruit to the desired temperatures of below -0.5 °C. According to the current best practises, fruit must be placed under forced-air cooling within six hours after packing, the fruit must be forced-air cool to under 10 °C in 12 hours and after 48 hours the fruit pulp temperature must be at -0.5 °C. The most frequently used method to reach the current best practises is to set the room setpoint to -1.5 °C from the start of the forced-air cooling stage. This method caused irregular temperature throughout the pallet, for example, outside facing cartons measured -0.3 °C and the inside facing cartons measured 8,3 °C as can be seen in the temperature data of Concept B. The Step-down cooling method took 60.7 hours to measure temperature below 2 °C, while Concept B used 60 hours and 20 minutes and Concept C 31 hours and 40 minutes. The step-down cooling method, Concept A took 10 hours to place the fruit under forced-air cooling after pack, 29 hours to reach temperatures below 10 °C and 75 hours to reach temperatures below -0.5 °C. Concept B took seven hours and 50 minutes to place the fruit under forced-air cooling after packing, 14 hours to reach temperatures below 10 °C and 237 hours to reach temperatures below -0.5 °C, the 237 hours were caused by fruit being cooled irregularly. Concept C took eight hours to place the fruit under forced-air cooling after pack, 11 hours to reach temperatures below 10 °C and 47 hours to reach temperatures below -0.5 °C.

During the Steri , loading and shipping stages Concept A had the greatest number of devices measuring temperatures of -1.5 °C and below; a total of 20 devices and the temperature break lasted for 39 hours and 10 minutes. Concept B indicated a temperature break in the final stage of the forced-air cooling stage by one device measuring temperature of -1.5 °C and below for nine hours. Concept B also indicated temperature breaks on two devices that lasted for 95 hours and 50 minutes by measuring temperatures of -1.5 °C and below. Concept C indicated temperatures breaks during the storage stage by six devices measuring temperatures of -1.5 °C and below for 75 hours and five devices indicating temperature breaks during the Steri measuring temperatures of -1.5 °C and below for 19 hours.

All the temperature breaks indicated from the final part of the forced-air cooling stage to the shipping stage can be avoided by better cold chain management and training to employees. Setpoint of rooms do not have to be set at -1.5 °C during the cold treatment stage, the cold treatment facilities can reduce the setpoint temperature if the desired temperatures are reached throughout the fruit.

Concept A, did not comply to the current best cooling practises due to the step-down cooling method, but it was the fastest a container was ever loaded to China following all the protocols from packing to loading.

CHAPTER 5: INTERPRETATION OF RESULTS

5.1 Introduction

In this chapter, the researcher interprets the results of the data analysis contained in Chapter 4.

This chapter begins with the findings of the 13 survey questions, followed by identifying and discussing the main findings of the three concepts. The chapter concludes with a discussion on the variables and concerns of the findings.

The three concepts described in Chapter 4 are Concept A (breaching experiment), Concept B (standard method) and Concept C (cold storage facility in the production area).

For this research, a temperature break in the cold chain was defined as any time in the data where the temperature reading measured 2 °C or warmer or -1.5 °C or colder for longer than 90 minutes. A temperature spike is defined as the temperature measuring 2 °C or warmer or -1.5 °C or colder for less than 90 minutes.

5.2 Main findings of the data analysis

5.2.1 Survey

The researcher used the survey to determine whether there is a need for training the industry on special market protocols.

The majority of the industry opted for the technology available by using the new registration method of registering electronically on the Phytclean website. A total of 90.3% of the participants in the survey selected the electronic registration method.

The survey revealed that:

- Seventy-four point two percent (74.2%) of the participants used the DALRRD website to obtain protocol information and 3.2% used the SATI website. These two websites are the most reliable sources of obtaining the information; 22.6% of the participants gathered the information from other sources in the industry.
- Ninety-point three percent (90.3%) of the participants were aware that one may not use previously used cartons for special markets.
- Ninety-three point five percent (93.5%) of the participants were aware that one may not stick box-end labels over one another.

- Only 64.5% of the participants knew the difference between the mark requirements, by answering that only China needs the storage facility on the carton.
- Sixty-one point three percent (61.3%) of the participants knew when a phytosanitary inspection was necessary.
- Only 51.6% of the participants knew the DALRRD rule that an inspection point must apply for an inspection and not the exporter or freight forwarder.
- Ninety-six point eight percent (96.8%) of the participants were aware that the original accompanying documents signed by the PPECB were necessary for the phytosanitary inspection to start. Most of the delays at the inspection points were due to having copies of accompanying documents and not the original documents.
- Thirty-two point three percent (32.3%) of the participants did not know the different cold treatment protocols summarised in the PPECB yellow chart.
- Twenty nine percent (29%) of the participants admitted that they did not know the different cold treatment protocols.
- Ninety-point three percent (90.3%) of the participants stated that the cold treatment process had an effect on the quality of the grapes and 93.5% of the participants knew the reason why the cold treatment process is necessary.
- One hundred percent (100%) of the participants need training and more information sessions on the cold treatment protocols.

Most participants knew where to find the cold treatment protocols, where to register and they answered the questions correctly. The need for information sessions and training on the cold treatment protocols is clearly indicated in the survey.

5.2.2 Concept A – Breaching experiment

It took an average of 10 hours from packing until the pallets were placed under forced-air cooling. Although, the current best practice is six hours. The pallet temperature was kept above 15 °C and below 22 °C, attempting to keep the temperature constant from packing to being placed under forced-air cooling. The best practice is to create a packing temperature environment of 18 °C, and therefore, the setpoint of the cooling unit in the refrigerated trucks collecting the pallets at the packhouse is set to 18 °C. The researcher tried to limit the risk of condensation by keeping the temperature constant until the forced-air cooling process could start.

Cold Treatment Facility A used the step-down cooling method. As mentioned in Chapter 2, no studies have been conducted on step-down cooling in the table grape industry. What was noted during these trials is that it took 17 hours longer than the current best practice to reach a pulp temperature of 10 °C and 27 hours longer than the current best practice to reach a pulp temperature of -0.5 °C using the step-down cooling method. The positive aspect of this cooling method is that the pulp temperature of all the devices is grouped on the graphs, meaning the pulp temperature profile through the pallets is similar.

Trial 1 loaded into a container destined for China in 73 hours and 30 minutes after being packed at Packhouse A. There is no recorded faster time for a container loaded from South Africa to China. If one looks at the China cold treatment procedure, this is the quickest time to date that a container destined for China has loaded from South Africa with cold treatment.

Of the 34 devices, 27 did not comply with the PPECB's cold treatment protocol. Two devices were above -0.5 °C and the remaining 25 devices were colder than -1.2 °C. The PPECB cold treatment protocol for China states that the pulp temperature of the grapes must be between -0.5 °C and -1.2 °C and when loaded, the temperature may increase to 0.8 °C (Henning & Chetty, 2020a:8). The shipping line and PPECB prefer the pulp temperature to be -0.8 °C to -1 °C in the forced-air cooling tunnels, as the pulp temperature increases with an average temperature of 0.3 °C when the pallets are moved from the forced-air cooling tunnels to the container (Hanekom, 2019, personal interview). Four devices positioned in the outside cartons of the pallets indicated an increased temperature during the trials of Concept A.

A clear increase in temperature is identified during the shipping stage of Concept A. The main reason is that the setpoint in the forced-air cooling tunnels is set at -1.5 °C and the setpoint of the cooling units in the container are set at -1 °C. The increase in temperature of the DAT causes the pulp temperature to increase.

5.2.3 Concept B – Standard method

It took an average of 7 hours and 50 minutes from packing until the pallets were placed under forced-air cooling. The current best practice is six hours. The pallets were loaded on flatbed trucks with no temperature control.

Cold Storage Facilities A and B used the standard method of forced-air cooling by setting the setpoint of the forced-air cooling room to -1.5 °C. It took an average of 14 hours to reach a pulp temperature of 10 °C, two hours longer than the current best practice. It took an average of 237 hours to reach the pulp temperature of -0.5 °C, 189 hours longer than the current best practice. The reason is that the PPECB allows temperatures below 1.5 °C to be exported to non-cold treatment markets, therefore, Cold Storage Facility A only force-cooled the pulp temperature to below 1.5 °C. It took an average of 60 hours and 33 minutes to cool the pulp temperature to under 1.5 °C. This high average length of time was caused by 10 devices not being below 1.5 °C when the pallets were moved out of the forced-air cooling tunnels to the holding rooms. One temperature device indicated two temperature breaks during the forced-air cooling stage at Cold Storage Facility B, due to warm pallets being added to the forced-air cooling tunnel.

Cold Storage Facility A uses tautliner trucks for transport of pallets to cold treatment facilities. There is no temperature control on these trucks and three devices indicated temperature breaks. One device in Trial 2 of Concept B indicated a temperature break when a pallet was offloaded at Cold Treatment Facility B and left in the airlocked area before being moved to a holding area. This break lasted for eight hours. One device in Trial 4 of Concept B indicated a temperature break during the storage stage. The pallet was moved out of the holding room to the airlocked area for the samples to be placed back onto the pallet and the pallet to be re-palletised.

Due to COVID-19, the shipping schedules changed, containers and vessels were less frequently available, causing delays in loading to the designated markets.

If one looks at the procedure and current data available, the lead time from packing the fruit and loading it to China, using Concept B, the standard method, is an estimated six days.

Packing the fruit, transferring it to a cold storage facility, forced-air cooling of the fruit and then transferring it to a cold treatment facility takes an estimated 72 hours. The phytosanitary inspection takes place on day four and fruit is placed in Steri on the evening of day four. Twenty-four hours after the Steri stage the pallets may load if the pulp temperature was below -0.5 °C for the last six hours. To reduce risk, the cold treatment facility plans the load with the PPECB and the shipping line for the morning of day six (Hanekom, 2019, personal interview).

Of the 28 devices, ten that went to a cold treatment market did not comply with the PPECB's cold treatment protocol. One device was above -0.5 °C and the remaining nine devices were colder than -1.2 °C.

5.2.4 Concept C – Cold treatment facility in the production area

It took an average of eight hours from packing until the pallets were placed under forced-air cooling. The current best practice is six hours. The pallets were loaded on flatbed trucks with no temperature control. Thirteen devices indicated a temperature break during the packing and loading onto flatbed trucks. The conclusion drawn was that the trucks were loaded just before lunchtime and the driver of the truck only made the delivery after his lunch break was finished.

Cold Treatment Facility C used the standard method of forced-air cooling by setting the setpoint of the forced-air cooling room to -1.5 °C. It took an average of 11 hours to reach the pulp temperature of 10 °C, one hour quicker than the current best practice. It took an average of 269 hours to reach the pulp temperature of -0.5 °C, 221 hours longer than the current best practice. Due to delays with the vessel, the Steri stage was delayed. Cold Treatment Facility C cooled trial fruit under -0.5 °C in 47 hours, one hour quicker than the current best practice. In Trial 2, the average temperature was higher due to the delays. Cold Treatment Facility C force-cooled Trial 2's fruit to -0.1 °C in 48 hours and stored the fruit at a room setpoint temperature of -0.5 °C until the Steri stage could start. During the storage stage, the phytosanitary inspection took place. This caused one device to indicate a temperature break due to the room being switched off for placing the sample cartons back and palletising the pallets.

Due to the COVID-19 pandemic, shipping schedules changed and the availability of containers and vessels was very limited, causing delays in loading to the destined markets.

If one looks at the procedure and current data available, the lead time from packing the fruit and loading it to China, using Concept C, the standard method, is an estimated three days, the same as Concept A.

Seven of the twelve devices that went to a cold treatment market did not comply with the PPECB's cold treatment protocol. All seven devices were colder than -1.2 °C.

5.2.5 Comparisons between the three concepts

The basic principles that are required to comply with the cold treatment protocols and extend the shelf life of table grapes are:

- Remove the warm air as soon as possible and use optimum and responsible cooling methods to cool the fruit pulp temperature to the desired temperatures.

- Limit the handling of table grapes in the supply chain because handling increases the risk of damage and warming of fruit.
- Regulate the temperature to reduce the risk of condensation and temperature breaks.
- Manage temperature control more efficiently.

Comparing the three concepts, the research identified the inaccuracies of each concept.

The current best practice is to place table grapes under forced-air cooling within six hours after packing. Concept A took 10 hours, Concept B took 7 hours and 50 minutes and Concept C took 8 hours. None of the three concepts achieved the current best practice time of six hours.

The reason for this is that the cold storage or cold treatment facilities are not on the same premises as the packhouses. The truck, a small flatbed or refrigerated truck, needs a full load to make the delivery financially viable. The producers or packhouse managers can increase their packing volumes by adding packers and increasing line speed to pack more pallets per hour but the risk is loss of packing quality and a drop in the morale of the workforce. Temperature management is an ideal method to use during the packing and transfer stage. Concept A used this method and no temperature increases were indicated. A constant temperature from packing until the forced-air cooling stage starts needs to be maintained. This reduces the risk of condensation and temperature breaks. Concept B had no temperature increases during this stage, due partly to temperature management. The packhouse kept the fruit in a holding room at 18 °C and loaded the fruit straight onto the truck that transported it to the cold storage facility. Concept C had temperature increases due to negligence. The pallets were removed from a regulated temperature holding room, packed on the trailer of the small flatbed truck, but the driver first took a lunch break before doing the delivery.

Forced-air cooling methods used in this research were the step-down method and the standard -1.5° setpoint method. The current best practice is 12 hours to reach a pulp temperature of 10 °C. The step-down method is slower and took 17 hours longer than the current best practice to reach a pulp temperature of 10 °C. The standard -1.5 °C setpoint method can achieve the current best practices for forced-air cooling. Concept B used 14 hours to reach a pulp temperature of 10 °C due to warm pallets being added to the forced-air cooling tunnel, slowing the process and indicating a temperature break, which could also have been caused by negligence. If the negligence can be avoided and tunnels are closed earlier, the 12-hour best practice can be achieved. Concept C used 11 hours to reach a pulp temperature of 10 °C.

The current best practice of cooling the pulp temperature to -0.5 °C in 48 hours is achievable, but the table grape industry in South Africa only cools the fruit to below 1.5 °C as the PPECB allows a pulp temperature of between 1.5 °C and -1.2 °C to be exported to all non-cold treatment markets. The industry cools the fruit to under 1.5 °C and after the phytosanitary inspection has been completed or the fruit has been allocated for a cold treatment market, the fruit moves to the Steri stage.

The step-down cooling method takes longer to achieve the desired temperatures, but the devices used in the research showed a more consistent pulp temperature and similar temperatures throughout the pallet. The standard method's devices showed inconsistent temperatures and different temperatures throughout the pallet, with the fruit in the outside carton layers being colder than the fruit in cartons of the inner layer. More time under forced-air cooling using the standard method will cause the pallets to have a more consistent pulp temperature, but the challenge is that the production area cold storage facilities are under immense pressure to rotate the forced-air cooling tunnels and as soon as the outside pallets are under 1.5 °C or the 48-hour mark has been reached, the pallets are removed from the forced-air cooling tunnels. It is important to make sure that the pallets are thoroughly cooled to the target temperature before removing them from the forced-air cooling tunnels.

Transferring cooled table grapes with a tautliner is not recommended as two devices in Concept B indicated temperature breaks during this stage of the chain.

Of the 44 devices, 41 devices measured temperatures colder than -1.2 °C and three devices were warmer than -0.5 °C. The cold treatment protocol is -0.5 °C to -1.2 °C;

The setpoint in the Steri tunnels is set at -1.5 °C and the container is set at -1 °C. During the loading and shipping stage, pulp temperature increased due to the delivery air of the container that was higher than in the Steri tunnels from which the pallets came out.

5.2.6 Concerns

The first concern is that 22.6% of the participants in the survey gathered their export and phytosanitary protocols from sources other than DALRRD and SATI. Only 3.2% used SATI's website to gather the information. It is important to determine the reasons why these participants do not use DALRRD and SATI to collect the necessary information.

Secondly, the current best practice of placing fruit under forced-air cooling within six hours after packing is not achievable with the first packed pallets of the day. Temperature management and regulating a constant temperature are recommended.

Thirdly, it is questioned whether the step-down cooling method is a new and innovative method that could be used in the table grape industry. Further research is necessary to determine this, but the current results and feedback from exporters look positive.

Fourth, the standard cooling method with a setpoint of -1.5 °C does not achieve the desired temperature throughout the pallet. The method and the current best practices may have to be revised due to new cooling technology and methods being used.

Fifth, with the focus on temperature management and optimal cold chain integrity, it is concerning that the industry still allows cooled table grape pallets to be loaded onto tautliners and transferred to cold treatment facilities. Temperature breaks will occur if an environment like this is created.

Sixth, the temperature breaks that occurred in Concept B are due to negligence or a lack of training. The first temperature increase occurred because warm pallets were added to the forced-air cooling tunnels. The temperature breaks occurred during the transfer stage, with Cold Storage Facility A using tautliners to deliver cooled pallets to cold treatment facilities. A temperature increase occurred in storage when the pallet was removed from the holding room by a forklift driver to re-palletise the pallet.

Seventh, temperature breaks occurred in Concept C, all due to negligence or a lack of training. Thirteen devices indicated a temperature increases during the packing and loading onto flatbed trucks. The conclusion is that the trucks were loaded just before lunchtime and the driver of the truck only made the delivery after his lunch break was finished. One device indicated a temperature increase during the storage stage, which was caused by the room being switched off for the pallet to be re-palletised.

The last concern is that 41 of 74 devices used for cold treatment markets were colder than -1.5 °C. Chilling injury, a physiological disorder, is a risk that can occur if temperature measures below -1.5 °C for long periods. The PPECB inspector must report immediately if temperatures below -1.5 °C are measured. The cold treatment facilities are forced by the shipping lines and PPECB inspectors to achieve a temperature of -0.8° to -1° in the Steri tunnels. A temperature of 0.3 °C is the difference between being too warm or too cold. The pulp temperature in the cartons on the pallet may differ by a few degrees due to airflow and packing material. The concern is that there is too much pressure on the cold treatment facilities, and therefore, they tend to go colder to avoid any rejection from the PPECB inspectors during the loading stage.

5.3 Conclusion

Training and supplying the essential skills to the industry are necessary to prevent any temperature break caused due to mismanagement of the cold chain and the cold treatment protocols.

Concept A and Concept C are the two methods by which fruit is loaded in the shortest lead time. Concept A (the breaching experiment) is a method that can add value to the industry by following the cold treatment protocols. This not only shortens the lead time but limits the handling of the fruit and reduces the hours of fruit under force air cooling conditions.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions of the study

The research attempted to assist the Hex River and Berg River production areas, focusing on the special cold treatment markets. The objective of the research was to create a method to overcome the logistical challenges faced by the Hex River and Berg River producers to supply excellent quality grapes. The method had to be more cost-effective, have shorter lead times and equip the Hex River and Berg River production areas with a standardised supply chain for the cold treatment markets.

The breaching experiment formed the main driver of the research as it overcomes a lot of logistical challenges faced by the Hex River and Berg River production areas. The method is more cost-effective, offers shorter lead times and can become a standardised chain in the supply chain of the cold treatment markets from the Hex River and Berg River production areas. For this research, a temperature break in the cold chain was defined as any time in the data where the temperature reading measured 2 °C or warmer or -1.5 °C or colder for longer than 90 minutes. A temperature spike is defined as any time when the temperature rises but does not follow the criteria of a temperature break. The method is more cost-effective due to the exporter or producer only receiving a steri invoice from the cold treatment facility. During the standard method, the cold storage facility in the production areas invoices the producer or exporter for force cooling and handling fees, whereafter the cold treatment facility invoices the producer or exporter for the steri force cooling fee. If the exporter or producer sends the fruit directly to the cold treatment facility, the cold treatment facility will only charge the steri force air cooling fee. For example, you have 21 pallets packed for China and you use the standard method, Concept B, the cooling and handling fee will be R533.00 per pallet x 21 pallets = R11 130.00 for the production area cold storage facility. The next step is the steri fee at the cold treatment facility—R730 per pallet x 21 pallets = R15 330.00. Adding R11 130.00 + R15 330.00 = R26 460.00. If the breaching experiment was conducted, the steri, cooling and handling fee would have been only R730 x 21 = R15 330.00, saving R11 130.00 per container (Crous, 2019).

A literature review was conducted to supply the reader with information relevant to the study to gain a better understanding of the topic. The South African fruit industry, the table grape industry and Hex River and Berg River production areas illustrated so that the reader could form the picture of where the Hex River and Berg River production areas forms part of the industry. The terms logistics, supply chain and perishable nature of table grapes were explained to emphasise their importance of the cold chain in the table grape industry.

A total of 98 Xsense BT9 radio frequency devices were used to monitor the pulp temperature every hour from insertion at the pack house to making contact with the last Xsense receiver. Three concepts were researched, using nine trials. Concept A was the breaching experiment, Concept B was the standard method used over the years and Concept C was a method to simulate a cold treatment facility in a production area.

6.1.1 Main logistical challenges faced by the Hex River and Berg River production areas

One of the main logistical challenges is the number of packhouses in the Hex River production area. There are 112 China-registered packhouses and 120 Vietnam-registered packhouses (DALRRD, 2020). There are not enough PPECB inspectors to service all the packhouses regularly (Mans, 2019). Packed grapes stand and wait for an inspector before the passed pallets are transported to a cold storage facility. The best practice of placing grapes under forced-air cooling within six hours after packing is not achieved and the wait for inspection is the main cause of this problem. This specific challenge can be overcome if the PPECB inspections can take place more frequently or the inspections take place at the cold storage or cold treatment facilities. This would prevent the delay in placing fruit under forced-air cooling because of waiting for a PPECB quality inspection to take place.

Another significant logistical challenge faced in the Hex River production area is the volume during certain peak periods in the season. There is currently no infrastructure in the Hex River production area that can handle cold treatment protocols and since only a small percentage of the grapes are currently being exported to cold treatment markets, it does not receive any special treatment at the cold storage facilities in the area. The breaching experiment, sending warm cold treatment fruit directly to the cold treatment facilities, is essential. This is not only for the shorter lead times, but also for less handling of pallets and getting the product to cold treatment facilities earlier in the cold chain so that the fruit can be prioritised and handled as per each protocol.

The Hex River production area's season only runs from week 50 to week 18. The packhouse managers and administrative personnel only work with the cold treatment protocols during those 21 weeks. It is essential for them to attend a refresher course at the beginning of each season to recap on each cold treatment and phytosanitary protocols. The refresher courses will also reduce the documentation errors made during the season causing unnecessary delays during phytosanitary inspections.

The breaching experiment is the way forward to overcome many of the logistical challenges faced in the Hex River and Berg River production areas and save money for the exporters and producers. The volume at the cold storage facilities in the area will be reduced, allowing for greater focus on the normal commercial markets. Less handling of pallets reduces the risk of damage to the cartons and pallet bases. Cooling of fruit in the cold storage facilities will be optimised as the tunnels do not need to be opened to take pallets out for transferring to cold treatment facilities. This will allow operators to focus on loading for export to normal commercial markets that make up the majority of the export markets. Producers and exporters will receive an invoice from only one cold storage facility instead of two. The challenge with the breaching experiment is to get the fruit to the cold treatment facility early enough for the fruit to meet the best practice of being placed under forced-air cooling within six hours after packing. The only way to overcome this challenge is to get more exporters and producers involved in this method, loading between all 112 packhouses, loading more frequently and not waiting for a PPECB inspector. PPECB inspection can take place at the cold treatment facility.

6.1.2 How the special cold treatment process can be improved

The main segments in the cold treatment process are the pulling of samples, phytosanitary inspection and the steri stage.

For the USA market, the sample pallet is palletised separately during the packing stage, which saves a lot of time during the process. For all the other markets, the inspection points are requested to pull sample cartons of each pallet listed in the consignment. The pulling process is labour-intensive, time-consuming and bears the risk of damage caused by further handling of the packed product. It would be beneficial to the industry if all the markets adhered to the same sample procedure as the USA sample protocol.

The DALRRD inspectors only work from 09:00 to 15:00, Monday to Friday (Crous, 2019). The set working hours make it very difficult for exporters to make a vessel in time if the fruit is not packed in time for the allocated inspection. The lead time will be shortened if the PPECB can conduct the phytosanitary inspection during the quality inspection. This means less handling of the fruit, while the PPECB could pull their own sample from the pack line, thereby reducing the risk of damage.

The current forced-air cooling technology makes it easier for cold treatment facilities to reach the desired temperatures. DALRRD and the PPECB will have to re-evaluate the cold treatment protocols as they did with the China protocol in the 2019/2020 season. The strict time regulations make it logistically challenging to make certain targeted vessels. If the USA, Japan, China, Thailand and Israel protocols can be amended to only the required target temperature and not set time requirements as the other cold treatment markets, shorter lead times will be achieved.

6.1.3 Can the process from harvesting to placing fruit under cold treatment be accelerated?

Yes, the breaching experiment makes this possible. Grapes were loaded in 73 hours 30 minutes after packing into a container destined for a cold treatment market. The process can be accelerated further if the phytosanitary inspection can take place at the same time as the PPECB quality inspection.

6.1.4 Do fluctuations in temperature cause a break in the cold chain?

Yes, temperature breaks occurred in all three concepts researched. The temperature breaks occurred due to human negligence and during the peak season. The production area cold storage facilities were under pressure to make space for warm fruit coming in, causing uneven and sub-optimum cooling of the fruit. Of the 40 devices, 27 indicated temperature breaks during the steri, loading and shipping stages by measuring -1.5 °C or colder.

6.2 The Breaching Experiment

The findings indicate that the breaching experiment, of delivering warm fruit directly from the Hex River production area to cold treatment facilities in the Cape Town area, will be beneficial for the industry.

Relief to the production area cold storage facilities will be given as they can focus on the normal commercial markets. Additional costs for the exporter and producer will be reduced as only one facility will charge cooling and handling charges. The risk of damages to the pallet base and cartons will be minimised as the palletised grapes will be handled less. Logistics and cold chain management through one facility will be easier to manage. The risk of temperature breaks will be reduced. Lead time will be decreased by two to three days, allowing exporters to get to the market sooner.

Improvements will be necessary if the breaching experiment is to reach the requirements of the current best cooling practices. If more producers and exporters use the breaching experiment concept, the refrigerated trucks can be loaded faster and more regularly, allowing the pallets to be placed under forced-air cooling within six hours after packing. The step-down method was used in this research study. As seen with the other concepts, the current best practice timeline can be achieved but further research will need to be conducted to determine whether the fruit will be cooled evenly throughout the pallet.

6.3 Recommendations

Short-term recommendation

Training. There is a need for pre-season training to refresh each packhouse and export team on the phytosanitary cold treatment market protocols. Appendix C will assist the industry with a summary of the phytosanitary requirements as well as the PPECB cold treatment requirements. Both the cold storage and cold treatment facilities need to train their operational employees on the cold chain, focusing on temperature breaks and what their influence is on fruit. This will reduce the human negligence causing temperature breaks.

Medium-term recommendation

Reconsider the sample used for the phytosanitary inspection. All phytosanitary inspections should inspect a sample packed at the packhouse, instead of the cold treatment facility pulling sample cartons of each pallet. This will shorten the lead time and reduce handling of palletised fruit. Cold treatment facilities will save on labour costs and in return, the inspection costs will be reduced.

Long term recommendation

Replace DALRRD with the PPECB in doing the phytosanitary inspections. The PPECB must conduct the phytosanitary inspection when conducting the required quality inspection. This will shorten the lead time and reduce handling of the fruit. All inspections should take place at the cold treatment facility. The lead time will be reduced as refrigerated trucks can load as soon as pallets are packed and there will be no need to wait for a PPECB inspector. Current best practice of placing fruit in forced-air cooling within six hours after packing will also be achieved. The industry should only use the breaching experiment, Concept A, for phytosanitary cold treatment markets. Benefits of the concept are discussed in section 6.2.

6.4 Future research

It is important to research step-down cooling used as a forced-air cooling method for all fruit commodities. This study showed that with the step-down cooling method, the pulp temperature data is consistent and grouped together, whereas with the method that is the current best practice, the temperature data differs from the outside of the pallet to the inside of the pallet, with the outside being colder than the inside.

Step-down cooling in its current state does not meet the requirements of the best cooling practices, but the feedback from industry was positive. Exporters are currently researching the step-down cooling method on Regal Seedless table grapes to normal commercial markets in Europe and the feedback is very positive.

Research should be conducted on whether or not the current best cooling practices are up to date with the logistical challenges, technology and grape varieties.

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APPENDIX A:
ETHICAL APPROVAL

UNIVERSITEIT
STELLENBOSCH
UNIVERSITY

9 November 2020

Project number: 13103

NOTICE OF APPROVAL

REC: Social, Behavioural and Education Research (SBER) - Initial Application Form

Project Title: Overcoming the logistical challenges faced by the South African table grape special cold sterilisation markets

Dear Mr Marthinus Pienaar

Your REC: Social, Behavioural and Education Research (SBER) - Initial Application Form submitted on 24 June 2020 was reviewed and approved by the REC: Social, Behavioural and Education Research (REC: SBE).

Please note below expiration date of this approved submission:

Ethics approval period:

Protocol approval date (Humanities)	Protocol expiration date (Humanities)
9 November 2020	8 November 2023

GENERAL REC COMMENTS PERTAINING TO THIS PROJECT:

INVESTIGATOR RESPONSIBILITIES

Please take note of the General Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with these guidelines.

If the researcher deviates in any way from the proposal approved by the REC: SBE, the researcher must notify the REC of these changes.

Please use your SU project number (13103) on any documents or correspondence with the REC concerning your project.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

CONTINUATION OF PROJECTS AFTER REC APPROVAL PERIOD

You are required to submit a progress report to the REC: SBE before the approval period has expired if a continuation of ethics approval is required. The Committee will then consider the continuation of the project for a further year (if necessary).

Once you have completed your research, you are required to submit a final report to the REC: SBE for review.

Included Documents:

Document Type	File Name	Date	Version
Research Protocol/Proposal	Proposal accepted by research committee - A	06/11/2019	1
Informed Consent Form	SU HUMANITIES Consent form template_Written 1	08/11/2019	1
Data collection tool	Survey	24/11/2019	1
Data collection tool	Interview guide	26/11/2019	1
Data collection tool	Observation Guide for the research thesis	24/06/2020	2
Default	RESPONSE LETTER	24/06/2020	1

If you have any questions or need further help, please contact the REC office at cgraham@sun.ac.za.
Sincerely,
Clarissa Graham

REC Coordinator: Research Ethics Committee: Social, Behavioral and Education Research

National Health Research Ethics Committee (NHREC) registration number: REC-050411-032.
The Research Ethics Committee: Social, Behavioural and Education Research complies with the SA National Health Act No.61 2003 as it pertains to health research. In addition, this committee abides by the ethical norms and principles for research established by the Declaration of Helsinki (2013) and the Department of Health Guidelines for Ethical Research: Principles Structures and Processes (2nd Ed.) 2015. Annually a number of projects may be selected randomly for an external audit.

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APPENDIX B:
GRAMMARIAN LETTER

22 Krag Street
Napier 7270
Overberg
Western Cape

02 June 2021

Stellenbosch Business School
PO Box 610
Bellville, CAPE TOWN
7530

Dear Sir/Madam,

DECLARATION OF LANGUAGE AND TECHNICAL EDITING

Overcoming the logistical challenges faced by the South African table grape phytosanitary cold treatment markets: A Case study focusing on the Hex River production area

Supervisor: Prof LL Goedhals-Gerber

This is to confirm that I, Cheryl Thomson, executed the language and technical editing of the above-titled thesis of Marthinus Christiaan Pienaar, student number, 14790696, project number 13103, at the UNIVERSITY OF STELLENBOSCH in preparation for submission of this thesis for assessment.

Yours sincerely

CHERYL M. THOMSON

Email: cherylthomson2@gmail.com

Cell: 0826859545

APPENDIX C: SUMMARY OF THE CURRENT PHYTOSANITARY COLD TREATMENT MARKETS FOR THE TABLE GRAPE INDUSTRY

Different cold treatment markets and cold treatment protocols

A. United States of America

All fruit must be force-cooled for a minimum of 72 hours. For the last 24 hours, the fruit must be below the target temperature of -0.6 °C at the cold storage facility where the container will be loaded. This is known as the land-base pre-cooling Steri process (PPECB, 2020:4). Before loading can take place, the cold storage facility must supply the authorised PPECB inspector with a physical printout of the fruit pulp temperature of the sensors for the required 72 hours as per protocol (Henning & Chetty, 2020c:8).

Each forced-cooling tunnel must be equipped with a minimum of two pulp sensors on the inside of the tunnel and one pulp sensor on the outside of the tunnel (Henning, 2019b:7).

The pre-cooling tunnel may only be opened or breached when the authorised PPECB inspector gives the go-ahead to load the container. The pallets will be loaded directly from the tunnel into the container and loading must be completed within 40 minutes (Henning & Chetty, 2020c:8).

The container thermostat is set to control the delivery air at -1.5 °C with the vents of the container kept closed (PPECB, 2020:4). A container is equipped with three USDA-approved temperature monitoring fruit pulp sensors that record temperature data every hour (Henning & Chetty, 2020c:5).

On-board probes are indicated in Figure C1 to give the reader a better understanding of on-board probes.

Figure C1: On-board USDA approved temperature monitoring fruit PULP SENSORS
Photo credit, Researcher 2020

Containers must be pre-cooled prior to being loaded. It is advisable to turn the refrigeration system of the container on 12 hours before loading (Henning & Chetty, 2020c:8).

A Genset is required to maintain the pre-cooling of the container before loading. During loading, the refrigeration system is switched off and after loading, the Genset must be turned on for the refrigeration system to be switched on again (Henning & Chetty, 2020c:8).

A Genset is a device that generates electricity. They are installed on the trailers carrying the special Sterilisation market containers. The Genset supplies electricity to the refrigeration system of the reefer container by being plugged into the Genset power outlet (Haasbroek, 2013:61).

Sensor number 1 must be inserted into the top layer of fruit on the top right corner of the first pallet loaded into the container on the left-hand side. Sensor number 2 must be inserted into the fruit on the pallet loaded in the middle of the container (pallet number 10) and the sensor must be placed close to the centre of the container at half the height of the palletised pallet. Sensor number 3 must be inserted into the fruit on the second last pallet row from the door on the left-hand side, at half the height of the palletised pallet (pallet number 18) (Henning & Chetty, 2020c:6).

The on-board probe sensor positioning is illustrated in Figure C2, to supply the reader with a visual illustration.

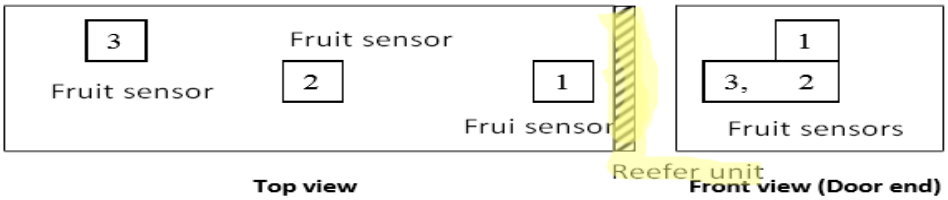

Figure C2: Sensor positioning in the container for the USA
Source: Henning and Chetty (2020c:6)

Authorised PPECB technical personnel supervise the loading process and insert the on-board fruit sensors into the fruit as per special market protocols (Henning & Chetty, 2020c:8).

The temperature measured by the fruit on-board sensors may not exceed -0.55 °C for 22 days, known as the on-board Sterilisation process. After 22 days with a pulp temperature of -0.55 °C or colder, the Sterilisation protocol is completed and step-up temperature options may be considered by the exporter (Henning, 2019a:2).

All table grape varieties can be exported to the USA. A few critical criteria must be obeyed to be able to export to the USA. These critical criteria are monitoring and control in the orchards, registrations, marketing requirements, inspections and cold treatment (USDA, 2007:8)

Monitoring and control in the orchards. It is mandatory that good agricultural practices are implemented for critical quarantine pests (USDA, 2007:11).

According to DAFF (2015c:1), good agricultural practices include:

- Weekly monitoring of bait traps for fruit flies,
- Weekly monitoring of pests by trained scouting,
- Spray programmes,
- Weekly vineyard block sanitation,
- All details must be updated and records stored.

Annual registration by DALRRD is compulsory for PUCs, PHCs, orchards and inspection points (DAFF, 2015c:1). Inspection points are also the cold storage facility where the cold treatment will take place (DAFF, 2015c:1). All loading cold storage facilities and exporters must register at the Food and Drug Administration of the United States Department of Health and Human Services (FDA) (FDA, 2003:3).

Marking requirements on each carton are the following (USDA, 2007:4-5)

- PUC as registered with DALRRD.
- PHC as registered with DALRRD.
- Date code and PPECB marking requirements.
- Only new cartons accepted. No used or relabelled cartons are accepted.

Inspections needed for being able to export to the USA are the following (USDA, 2007:11):

a) Pre-harvest USDA-APHIS and DALRRD inspections will take place during the growing season to monitor orchards and vineyards and to ensure that good agricultural procedures are implemented (USDA, 2007:11).
b) The PPECB will do a quality inspection.
c) Phytosanitary inspections will be conducted by DALRRD and USDA-APHIS on each consignment packed for the USA. The minimum consignment size is five pallets per PUC per cultivar and the maximum number of PUCs on a consignment is three (DAFF, 2015c:3).

An accompanying document represents the consignment and the accompanying document is universally the same for each market (PPECB, 2016:1).

A biometric sampling method is used to pull the sample for each consignment at the packhouse. These sample cartons are palletised at the packhouse on separate pallet bases and form part of the consignment (DAFF, 2015c:2).

The biometric sample protocols are (USDA, 2007:10).

- Consignment size - Biometric sample size for 4.5 kg cartons
- 0 to 160 cartons - 25 cartons
- 161 to 800 cartons - 50 cartons
- More than 800 cartons - 75 cartons

To determine the sample interval, it is necessary to establish the inspection unit or consignment size. For example, if the consignment size is 6000 cartons then the biometric sample must be

75 cartons as per the biometric sample protocol. Next, one must divide the inspection unit size by the biometric sample size; for example, 6000/75 = 80 (the sampling interval will be 80). Then, randomly select a number between 1 and 80 and that will become the numbered mark on the first sample carton. Every 80th carton on the pack line, packed for the specific consignment will become part of the sample pallet until the biometric sample size of 75 has been filled. All cartons on the sample pallet must be numbered and labelled. For this example, the number 10 was selected for the first sample carton. Then 80 was added to each number to obtain the number sequence (USDA, 2007:10).

If there is more than one cultivar or PUC on an Accompanying Document, the following calculation will apply for drawing the sample at the packhouse, representing the sample size (USDA, 2007:10).

Producer	Inspection Unit Size	Biometric Sample Size
1	10 pallets: 1600 cartons	1600/3,200 x 75 = 37.5 round to 37
2	5 pallets: 800 cartons	800/3,200 x 75 = 18.75 round to 19
3	5 pallets: 800 cartons	800/3,200 x 75 = 18.75 round to 19

If the carton total for the consignment is 3,200 cartons, the biometric sample will be 75 (USDA, 2007:10). First divide the carton quantity of each PUC by the total of the consignment cartons. Next, multiply the answer with 75 to determine each PUC's number of cartons for the sample of 75 cartons (USDA, 2007:10).

The sample selection for organic grapes is the same, but two samples are necessary, one for DALRRD and one for USDA. Therefore, if the biometric sample is 75 cartons, 150 cartons will be inspected, 75 cartons for DALRRD and 75 cartons for USDA (USDA, 2007:10).

During the phytosanitary inspection, DAFF and USDA will reject on the following critical criteria: marketing requirements, documentation and quarantine pests (DAFF, 2015c:3).

Critical Quarantine Pests include (USDA, 2007:14-18):

- *Acia lineatifrons* – Vine Leafhopper
- *Antestia variegate* – Stinkbug
- *Bagrada hilaris* – Bagrada bug
- *Calpe emarginata* – fruit piercing moth
- *Carbula marginella* – Grain stink bug

- *Ceratitis capitate* – Mediterranean fruit fly
- *Ceratitis rosa* – Natal fruit fly
- *Cryptolaryn vitis* – Snout beetle
- *Cryptophlebia leucotreta* – False codling moth
- *Dischista cincta* – Flower beetle
- *Epichoristodes acerbella* – Leaf roller
- *Gryllotalpa africana* – African mole cricket
- *Heliothrips sylvanus* – Guava thrips
- *Macciademus diplopterus* – South African grain bug
- *Nipaecoccus vastator* – Karoo thorn mealybug
- *Raglius apicalis* – Seed bug
- *Xiphistes furcicornis* – Treehopper
- *Eutetranychus orientalis* – Oriental red mite
- *Theba pisana* – White garden snail

B. Japan

The market opened in 2011 for South Africa to export grapes to Japan, but only the Barlinka variety are allowed to be exported (DAFF, 2011a:1).

Registrations of vineyard blocks, production units, packhouses and inspection cold treatment facilities are critical factors needed for being able to export to Japan (DAFF, 2011a:1). Inspection and marketing requirements are also compulsory (DAFF, 2011a:6).

Registration is done annually for vineyard blocks, PUCs, PHCs and inspection cold Sterilisation facilities by DALRRD (DAFF, 2011a:5). Japanese officials will inspect packhouses and cold treatment facilities (DAFF, 2011a:3). Only DALRRD registered and Japanese-passed facilities may handle grapes destined for Japan (DAFF, 2011a:6).

Standard marketing requirements for grapes exported from South Africa are required as per the PPECB minimum standards (Codex Alimentarius, 2007:1). The minimum requirements are the following: Commodity, variety, class, pack type, target market, PHC, PUC, vineyard blocks, berry size and the wording produce of South Africa (Codex Alimentarius, 2007:2). The following wording must be on the box-end label of each carton packed for Japan, S.A.P.Q. and 日本. (DAFF, 2011b:6).

The following inspections will take place before grapes may be exported to Japan.

A PPECB quality inspection will take place on 2% of the consignment packed as per the minimum standard set by the industry (Codex Alimentarius, 2007:2).

DALRRD will conduct a phytosanitary inspection on 2% of the consignment size (DAFF, 2011b:6). The sample will be drawn randomly from all the cartons on the consignment and the accompanying document will represent the consignment size (DAFF, 2011b:5). *Ceratitis capitateI* (Mediterranean fruit fly) is seen as the most critical quarantine pests and if found, investigations would be conducted to determine the cause (DAFF, 2011b:3).

Import inspection will take place at the ports of import, confirming the grapes and phytosanitary certificate (DAFF, 2011b:7)

Only grapes from the Barlinka cultivar may be exported to Japan from South Africa. All fruit must be force-cooled to a target temperature below -0.5 °C and above -1.2 °C for 72 hours at the cold storage facility where the container will be loaded, known as land-base pre-cooling Steri (Henning 2019a:5). The cold storage facility must supply the authorised PPECB inspector with a physical printout of the fruit pulp temperature of the tunnel sensors for the required 72 hours as per protocol (Henning & Chetty, 2020b:8). Each forced-air cooling tunnel must be equipped with a minimum of two pulp sensors on the inside of the tunnel and one pulp sensor on the outside of the tunnel (Henning 2019a:5 The pre-cooling tunnel may only be open or breached when the authorised PPECB inspector gives the go-ahead to load the container. The pallets will be loaded directly from the tunnel to the container and loading must be completed within 40 minutes (Henning & Chetty, 2020c:8). Fruit that has passed phytosanitary inspections for Japan may not be stored with fruit destined for other countries. Only fruit that has passed the inspections destined for Japan may be stored in the same cold room (Henning & Chetty, 2015:6).

The container thermostat is set to control the delivery air at -0.5 °C with the vents of the container kept closed (Henning & Chetty, 20154). The container is equipped with three on-board temperature monitoring fruit pulp sensors and will be placed in position as per the instructions of the Japanese authorities (Henning & Chetty, 2015b:6). Containers must be pre-cooled prior to being loaded. It is advisable to turn the refrigeration system of the container on 12 hours before loading (Henning & Chetty, 2015:8). A Genset is required to maintain the pre-cooling of the container before loading. During loading, the refrigeration system will be switched off and after loading, the Genset will be turned on for the refrigeration system to be switched on again (Henning & Chetty, 2015:8).

A PPECB authorised inspector will insert the on-board fruit sensors as specified by the Japanese authorities, namely fruit sensor number 1 must be placed into the fruit in the carton in the second layer from the top of the first pallet loaded into the right-hand side of the container. Sensor number 2 must be placed into the fruit in a carton in the centre of the pallet in the middle of the container (pallet number 10 or 11). Sensor number 3 must be placed into the fruit in the carton on the second layer from the bottom of the last pallet on the left-hand side at the door (Henning & Chetty, 2015:6).

The on-board probe sensor positioning is indicated in Figure C3, to supply the reader with a visual illustration.

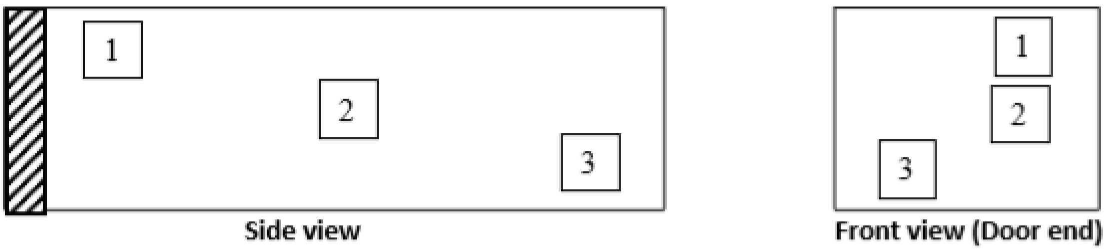

Figure C3: Sensor positioning in the container for Japan
Source: Henning and Chetty (2015:7)

The temperature measured by the fruit on-board sensors may not exceed 0.8 °C for 16 days, known as the on-board Sterilisation process. After 16 days with a pulp temperature of 0.8 °C or colder, the Sterilisation protocol is completed and step-up temperature options may be considered by the exporter (Henning & Chetty, 2015:7).

C. Israel

All grape varieties, but only grapes from the Northern Cape, Hex River and Berg River production areas can be exported to Israel (DAFF, 2015b:2). Registrations, vineyard block management, marking requirements, inspections and cold Sterilisation are the requirements necessary to be able to export to Israel (DAFF, 2015b:2).

Production units, packhouses, vineyard blocks and inspection points at cold Sterilisation facility need to register annually by DALRRD (DAFF, 2015b:2). DALRRD must send the Plant Protection and Inspection Services of Israel (PPIS) a list of all the approved vineyard blocks, maps showing their location, a list of approved packhouses and a report on the pheromone trapping surveys for *Ceratitis rosa* (FCM) for each approved vineyard blocks (Opatowski, 2016:5)

All vineyards must be free from citrus blackfly and at least 500 m from any citrus groves (Opatowski, 2016:5). Pheromone-specific traps must be used to monitor the vineyards and all vineyards must be free of FCM for at least three months prior to export to Israel (DAFF, 2015b:2). Vineyards must be free of pernicious scale for the last two growing seasons (DAFF, 2015b:2).

A pheromone trap is illustrated in Figure C4.

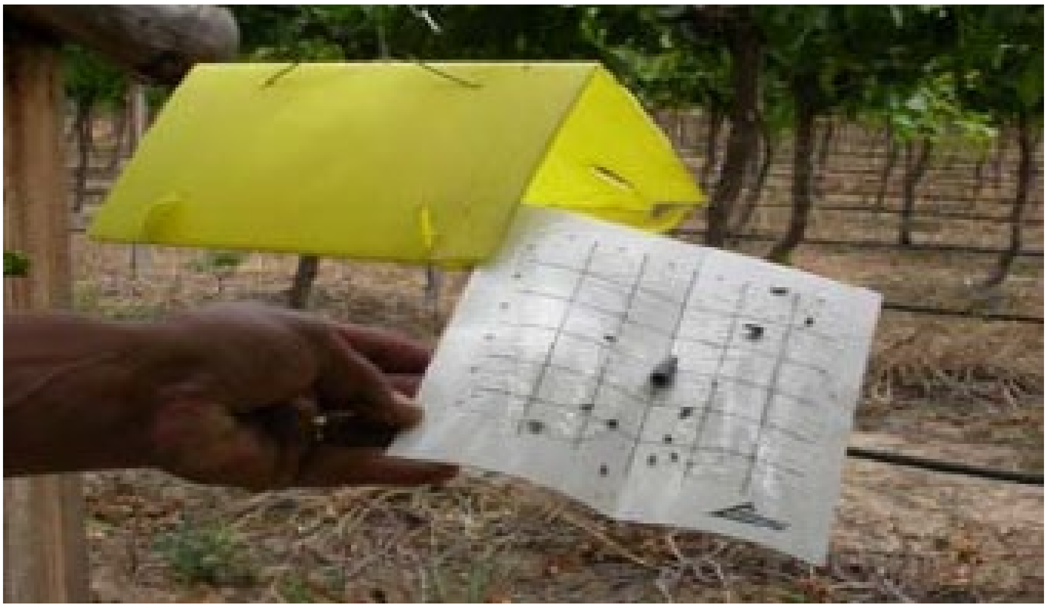

Figure C4: Pheromone trap
Source: de Villiers (2006:28)

Stem barriers must be applied on all stems in the Hex River and Berg River regions for vineyard blocks registered for exporting to Israel. Plantex has been approved by PPIS and is the most used product for stem barriers (DAFF, 2015b:3).

Application of the stem barriers must be applied during the winter after pruning and before the third week of September (Opatowski, 2016:10). All old and loose bark must be removed from the stems below the crown, either 25 cm in length or the whole stem. All the removed bark must be burned (DAFF, 2015b:3). Stem barriers must be 10 cm wide around the stems, poles and wire supports (DAFF, 2015b:3). Stem barriers are illustrated in Figure C5.

Figure C5: Stem barriers applied for Israel orchard
Photo credit, Researcher, 2020

It is mandatory the implementation of good agricultural practices (GAPs) and weekly monitoring of pests (DAFF, 2015b:3).

According to DAFF (2015b:3), marketing requirements for all cartons packed for Israel are:

- Registered PUC, PHC and orchard numbers must appear on the box-end label of all cartons.
- Only new, unused cartons are acceptable.
- Date code of packing must appear on all box-end labels.

Four different inspections take place before the consumer can enjoy the grapes in Israel.

a) DALRRD will inspect orchards three times a year in August, November and January, to verify if all monitoring, GAPs and stem barriers comply with the protocol (DAFF, 2015b:3).

b) The PPECB will do a quality inspection on 2% of the packed consignment at the packhouse as per the minimum standard set in the CODEX (Codex Alimentarius, 2007:2). No intake documents or Accompanying documents may be signed by the phytosanitary inspection cold Sterilisation facility (DAFF, 2015b:4).

c) DALRRD will do a phytosanitary inspection at the registered inspection cold Sterilisation facility, making sure no quarantine pests are found in the consignment (Opatowski, 2016:6).

d) Samples drawn from each pallet should be according to the consignment size as per the Accompanying document (Opatowski, 2016:6). Only one PUC, PHC, vineyard block and variety are allowed per consignment. If more appear on the Accompanying document, the phytosanitary inspection will not take place (DAFF, 2015b:4).

Table C1 indicates the number of samples that need to be drawn according to the consignment size per cartons.

Table C1: Sample size according to consignment size

CONSIGNMENT SIZE (CARTONS)	SAMPLE SIZE DRAWN (CARTONS)
1-160	25
161-800	50
>800	100

Source: Opatowski (2016:6)

On arrival, a PPIS inspector will select a random sample and inspect for any pests, soil, sand, leaves and plant debris (Opatowski, 2016:8).

Critical quarantine pests according to DAFF (2015b:1) are:

- *Ceratitis capitate* – Mediterranean fruit fly
- *Ceratitis rosa* – Natal fruit fly
- *Bactrocera dorsalis* – Invasive fruit fly
- *Aleurocanthus wooglumi* – Citrus blackfly
- *Thaumatotibia leucotreta* – False codling moth
- *Gryllus bimaculatus* – Cricket
- *Phlyctinus callosus* – Banded weevil
- *Quadraspidiotus perniciousus* – Pernicious scale

- *Acia lineatifrons* – Leafhopper
- *Aleurocanthus spiniferus* – Orange spiny whitefly
- *Cryptolarynx vitis* – Vine snout beetle
- *Eremnus spp* – Snout beetle
- *Pseudococcus calceolariae* – Scarlet mealy bug
- *Xanthomonas ampelina* – Bacterial blight
- *Guignardia bidwellii* – Black rot
- *Monilinia fructucola* – Brown rot

All fruit must be force-cooled to a target temperature below -0.6 °C and above -1.2 °C for a duration of 72 hours at the cold storage facility where the container will be loaded, known as land-base pre-cooling Steri (Henning, 2019a:6). The cold storage facility must supply the authorised PPECB inspector with a physical printout of the fruit pulp temperature of the tunnel sensors for the required 72 hours as per protocol (Henning & Chetty, 2017a:9). Each forced-air cooling Sterilisation tunnel must be equipped with a minimum of two pulp sensors on the inside of the tunnel and one pulp sensor on the outside of the tunnel (Henning 2019a:6). The pre-cooling Steri tunnel may only be opened or breached when the authorised PPECB inspector gives the go ahead to load the container. The pallets will be loaded directly from the tunnel to the container and loading must be completed within 40 minutes (Henning & Chetty, 2017a:9).

The container thermostat is set to control the delivery air at -1.5 °C with the vents of the container kept closed (Henning & Chetty, 2017a:3). The container will be equipped with three USDA-approved on-board temperature monitoring fruit pulp sensors (Henning & Chetty, 2017a:6). Containers must be pre-cooled prior to being loaded. The refrigeration system of the container must run continuously for a minimum of 12 hours at -0.55 °C or colder and a downloaded printout must be delivered to the loading point to serve as proof (Henning & Chetty, 2017a:8). A 24-hour empty test must also take place before loading can start. The empty test can form part of the 12-hour pre-cooled period (Henning & Chetty, 2017a:6). Grapes must be used for the empty test, as the grapes are placed on the sensors and sensors are positioned, as they would be placed in the loading process (Henning & Chetty, 2017a:5). The temperature of the sensors must remain at -0.55 °C or colder for at least 24 hours (Henning & Chetty, 2017a:5).

To supply the reader with a visual illustration, photos were taken by the researcher of how the on-board probes sensors are placed during the empty test as indicated in Figure C6.

Figure C6: Grapes placed on fruit sensors for empty test

Photo credit, Researcher, 2020

A Genset is required to maintain the pre-cooling of the container before loading. During loading, the refrigeration system will be switched off and after loading, the Genset must be turned on for the refrigeration system to be switched on again (Henning & Chetty, 2017a:9).

A PPECB authorised inspector must conduct the placement of the sensors, namely fruit sensor number 1 must be placed into the fruit in the carton on the second layer from the floor, in the centre of the corner carton nearest to the cooler and right-hand side wall. Sensor number 2 must be placed into the fruit in a carton in the centre of the pallet in the middle of the container (pallet number 10 or 11). Sensor number 3 must be placed into the fruit in the carton in the second layer from the top of the last pallet on the left-hand side at the door (Henning & Chetty, 2017a:6).

The on-board probe sensor positioning is indicated in Figure C7, to supply the reader with a visual illustration.

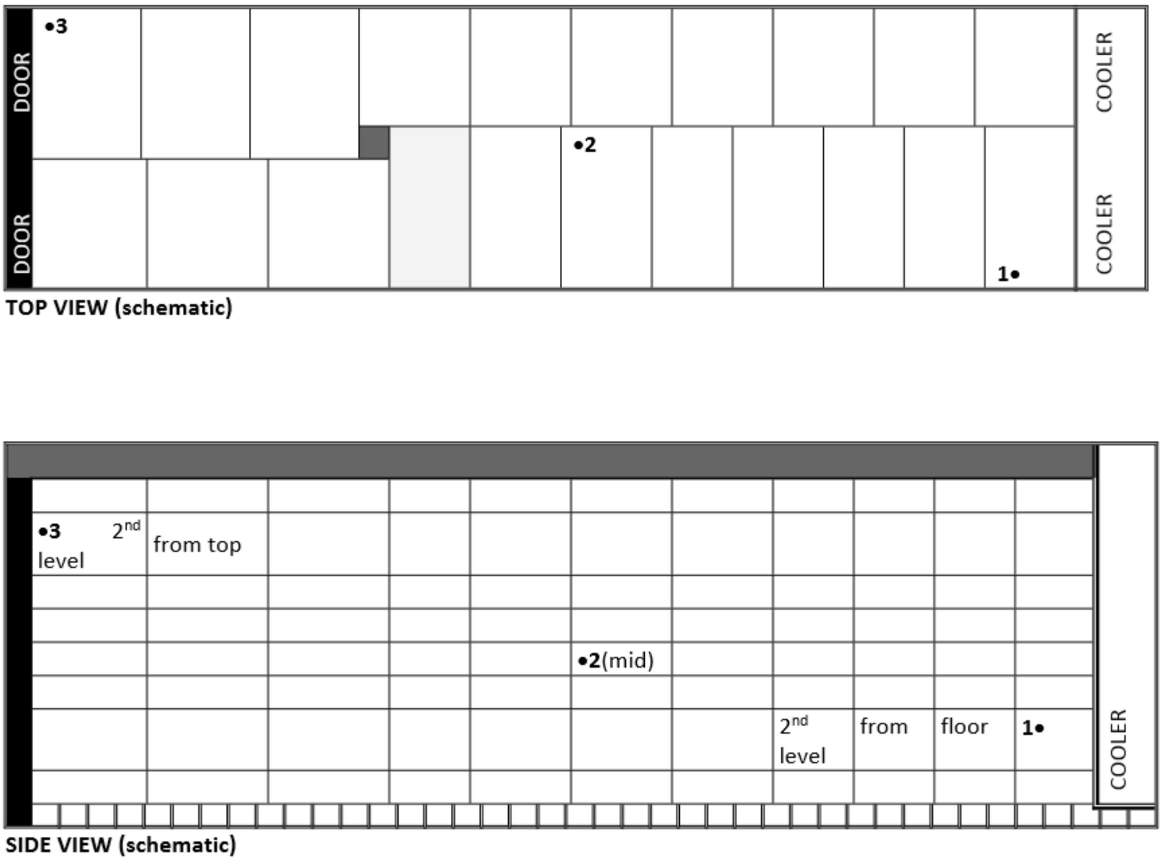

Figure C7: Sensor positioning in the container for Israel

Source: Henning and Chetty (2017a:7)

The temperature measured by the fruit on-board sensors may not exceed -0.6 °C for 22 days, known as the on-board Sterilisation process. After 22 days with a pulp temperature of -0.6 °C or colder the Sterilisation protocol is completed and step-up temperature options may be considered by the exporter (Henning, 2019a:5).

D. Thailand

All varieties of grapes from all production regions in South Africa are allowed to be exported to Thailand (DAFF, 2015a1).

Import permits, registrations, vineyard block requirements, packhouse requirements; requirements for quarantine insect pests and cold treatment are all critical criteria to be able to export to Thailand (Kingdom of Thailand Department of Agriculture, 2015:2).

The Kingdom of Thailand Department of Agriculture will issue import permits for each importer and these import permits are required for all exports of grapes to Thailand (Kingdom of Thailand Department of Agriculture, 2015:2).

Vineyard block requirements: all blocks must be registered by DALRRD and records must be available upon request (Kingdom of Thailand Department of Agriculture, 2015:2). Good agriculture practices, integrated pest management and orchard sanitation is compulsory for the export to Thailand (Kingdom of Thailand Department of Agriculture, 2015:2).

All packhouses and inspection cold storage facilities must be registered by DALRRD for export to Thailand (Kingdom of Thailand Department of Agriculture, 2015:2).

The following marketing requirements are mandatory for export to Thailand (DAFF, 2015a:2).

- The wording “Product of South Africa” must appear on the business end of each carton.
- Name of exporting companying must appear on the box-end label.
- Commodity and cultivar name must appear on the box-end label of each carton.
- PUC and PHC codes must appear on the box-end label of each carton.
- The wording “Export to Thailand” must appear on all cartons or on the four sides of each palletised pallet.
- No used or relabelled cartons will be accepted.

The following inspection will take place before any grapes may be exported to Thailand (Kingdom of Thailand Department of Agriculture, 2015:5).

The PPECB will do a quality inspection on 2% of the consignment presented for inspection (Codex Alimentarius, 2007:2). Phytosanitary inspection will take place at the registered inspection cold Sterilisation facility. The inspection will be conducted by DALRRD (Kingdom of Thailand Department of Agriculture, 2015:5).

The minimum consignment allowed for inspection will be five pallets per consignment, with the accompanying document representing the consignment (DAFF, 2015a:3). Three PUCs and one PHC are allowed per consignment. (DAFF, 2015a:3). A 2% sample will be drawn from each pallet on the consignment at the inspection point (DAFF, 2015a:3). Only original accompanying documents will be accepted and no intake documents to be stamped by PPECB at the inspection points (DAFF, 2015a:3).

Critical quarantine pests include (DAFF, 2015a:1):

- *Ceratitis capitate* – Mediterranean fruit fly
- *Ceratitis rosa* – Natal fruit fly
- *Thaumatotibia leucotreta* – False codling moth
- *Pseudococcus viburni* – Californian mealy bug
- *Anoplolepsis custodiens* – Common pugnacious ant
- *Helix aspera* – Common snail
- *Theba pisana* – White garden snail
- *Panonynchus ulmi* – European red spider mite
- *Tortrix capensana* – Pear leaf roller

DALRRD must approve the calibration of the probe on-board sensors of each container destined for loading to Thailand (DAFF, 2015a:3). During the cold Sterilisation process, DALRRD must be present and supervise the PPECB during the insertion of the on-board sensors (Kingdom of Thailand Department of Agriculture, 2015:4).

Import inspection must be conducted and the inspector will randomly select 600 bunches for the inspection (Kingdom of Thailand Department of Agriculture, 2015:6).

All fruit must be forced-air pre-cooled to a temperature below -0.6 °C and above -1.2 °C for 72 hours (PPECB, 2020:4). The cold storage facility must supply the authorised PPECB inspector with a physical printout of the fruit pulp temperature of the tunnel sensors for the last 72 hours before loading (PPECB, 2020:5). Each forced-air cooling tunnel must be equipped with a minimum of two pulp sensors on the inside of the tunnel and one pulp sensor on the outside of the tunnel (Henning & Chetty, 2020f:5). The pre-cooling Steri tunnel may only be open or breached when the authorised PPECB inspector gives the go ahead to load the container. The pallets will be loaded directly from the tunnel to the container and loading must be completed within 40 minutes (Henning & Chetty, 2020f:9).

A container thermostat is set to control the delivery air at -1.5 °C with the vents of the container kept closed (PPECB, 2020:5) The container will be equipped with three USDA approved temperature monitoring fruit pulp sensors that record temperature data every hour (Henning & Chetty, 2020f:6).

Containers must be pre-cooled prior to being loaded. It is advisable to turn the refrigeration system of the container on 12 hours before loading (Henning & Chetty, 2020f:9). DAFF must be present during the calibration of the on-board probes at the container depot (Henning & Chetty, 2020f:5). A Genset is required to maintain the pre-cooling of the container before loading. During loading, the refrigeration system will be switched off and after loading, the Genset must be turned on for the refrigeration system to be switched on again (Henning & Chetty, 2020f:9).

Sensor number 1 must be inserted into the fruit in the first pallet loaded into the container on the left-hand side, at half the height of the palletised pallet in the sidewall carton. Sensor number 2 must be placed into the fruit in a carton in the centre of the pallet in the middle of the container (pallet number 10 or 11). Sensor number 3 must be inserted into the fruit on the second last pallet row from the door on the right-hand side, 1.5 meters from the door, at half the height of the palletised pallet (pallet number 18) on the right-hand side of the pallet (Henning & Chetty, 2020f:6).

The on-board probe sensor positioning is indicated in Figure C8, to supply the reader with a visual illustration.

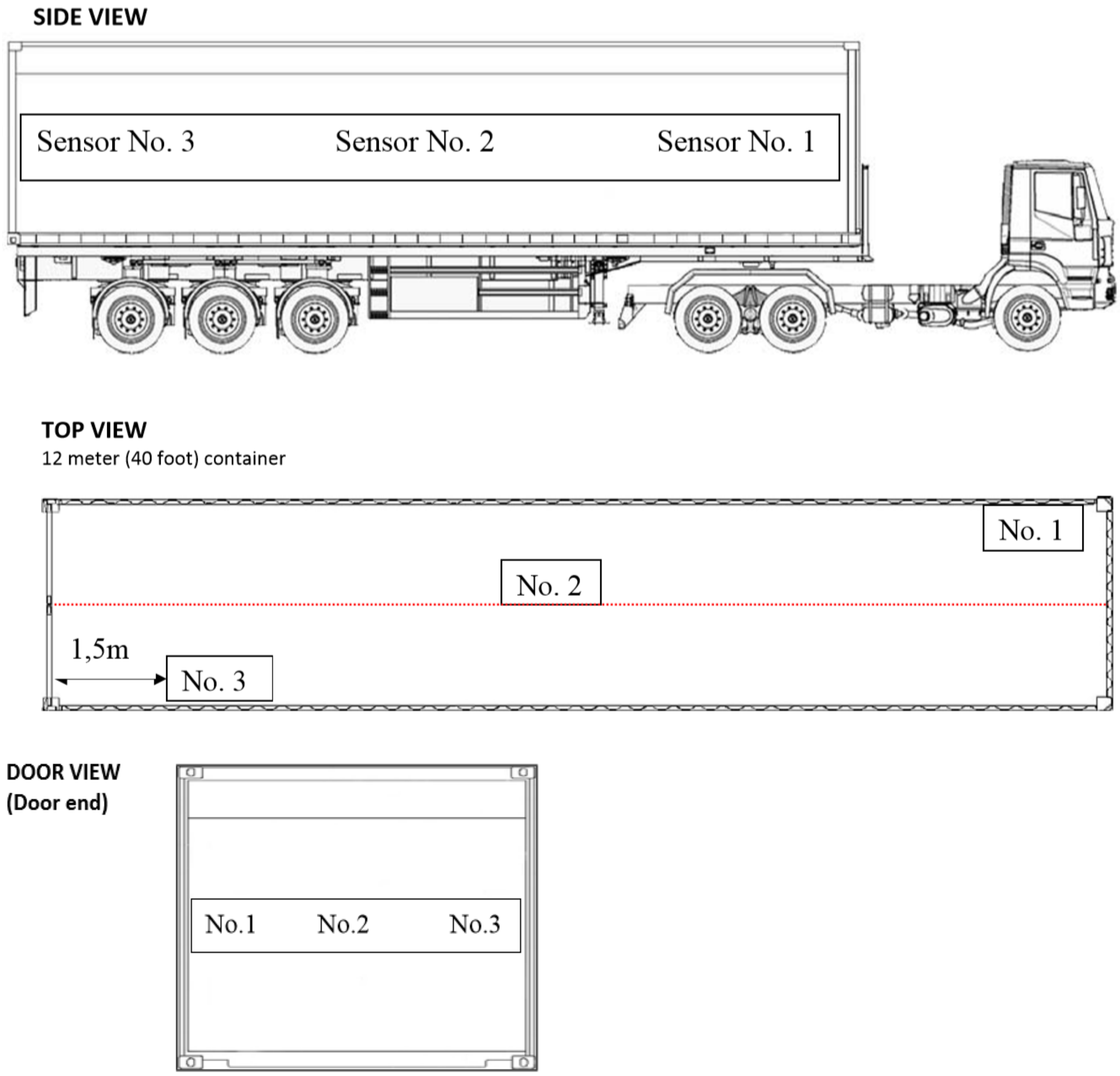

Figure C8: Sensor positioning in the container for Thailand

Source: Henning and Chetty (2020h:7)

Authorised PPECB technical personnel supervise the loading process and insert the on-board fruit sensors into the fruit as per special market protocol. A DAFF officer or a certified official in the country of origin will be present during the placement of the fruit sensors in the container. The tip of the sensor must not extend beyond the fruit (Henning & Chetty, 2020f:8).

The temperature measured by the fruit on-board sensors may not exceed -0.55 °C for 22 days, known as the on-board Sterilisation process. After 22 days with a pulp temperature of -0.55 °C or colder, the Sterilisation protocol is completed and step-up temperature options may be considered by the exporter (PPECB, 2020:5).

E. India

Inspections, marking requirements and land-base cold treatment protocol are requirements necessary for exporting to India (Henning & Chetty, 2019c:1).

The following marking requirements are necessary for exporting fruit to India (Codex Alimentarius, 2007:1). An India box-end label is illustrated in Figure C9.

- The minimum requirements are the following: Commodity, variety, class, pack type, target market, PHC, PUC, vineyard blocks, berry size and the wording produce of South Africa (Codex Alimentarius, 2007:4)
- Exporter name and address
- Name and address of the importer
- Date of packing
- Vegetarian: Yes
- Green circle symbol
- Best before date

EXPORTER NAME AND ADDRESS				
EXPORTER / MANUFACTURER & PACKER NAME AND ADDRESS				
NAME AND ADDRESS OF THE IMPORTER				
COUNTRY OF ORIGIN	SOUTH AFRICA		fssai	
NAME OF COMMODITY	GRAPES		FSSAI LIC. NO.	10018011005113
VARIETY / GRADE	CRIMSON SEEDLESS			
DATE OF PACKING	MARCH	2020	VEGETARIAN : YES	
NET WEIGHT	4.5KG		COUNT : AS MENTIONED ON BOX	
LOT #	03/2019		BEST BEFORE : MONTH JUNE	

Figure C9: India additional label with green circle symbol

Photo credit, Researcher, 2020

The following inspections must take place before fruit may be exported to India.

a) The PPECB will do a quality inspection on 2% of the consignment size as per the minimum standards (Codex Alimentarius, 2007:1).
b) DALRRD will conduct a phytosanitary inspection on 2% of the consignment. The consignment size will be the number of cartons loaded per container (Henning & Chetty, 2019c:6).

Land-based cold Steri treatment is the method used for loading to India. The first option is for all fruit to be forced-air pre-cooled to a temperature below 0 °C and above -1.5 °C. The temperature must be maintained for 10 days. The second option is to force-air pre-cool the fruit to a temperature below 0.55 °C and above -1.5 °C, maintaining the temperature for 11 days (Henning, 2019a:5).

The cold storage facility must supply the authorised PPECB inspector with a physical printout of the fruit pulp temperature of the tunnel sensors for the last 10 days of the fruit pulp temperature below 0 °C or 11 days below 0.55 °C before loading can take place (PPECB, 2020:4). Each forced-air cooling Steri tunnel must be equipped with a minimum of two pulp sensors on the inside of the tunnel and one pulp sensor on the outside of the tunnel (Henning, 2019b:5). The pre-cooling Steri tunnel may only be open or breached when the authorised PPECB inspector gives the go-ahead to load the container. The pallets will be loaded directly from the tunnel to the container and loading must be completed within 40 minutes (Henning & Chetty, 2019c:8).

The container thermostat is set to control the delivery air at -0.5 °C or 0.5 °C with the vents of the container kept closed (PPECB, 2020:4). No on-board sensors will be inserted into the container, only the three sensors of the cold Steri tunnel are used (Henning & Chetty, 2019c:1). The cold Steri process is finished as soon as the PPECB inspector approves the land-base process (PPECB, 2020:4).

F. Indonesia

All fruit must be force-cooled to the target temperature of 0.0 °C at the cold storage facility where the container will be loaded, known as the land-base pre-cooling Steri process (PPECB, 2020:5). Before loading can take place, the cold storage facility must supply the authorised PPECB inspector with a physical printout of the fruit pulp temperature of the sensors. The PPECB inspector can request up to a 12-hour printout (PPECB, 2020:4). Each forced-air cooling Steri tunnel must be equipped with a minimum of two pulp sensors on the inside of the tunnel and one pulp sensor on the outside of the tunnel (Henning & Chetty, 2018:5). The pre-cooling Steri tunnel may only be open or breached when the authorised PPECB inspector gives the go-ahead to load the container. The pallets will be loaded directly from the tunnel to the container and loading must be completed within 40 minutes (Henning & Chetty, 2020e:9).

A container thermostat is set to control the delivery air at -0.5 °C with the vents of the container kept closed (PPECB, 2020:5). The container will be equipped with three USDA-approved temperature monitoring fruit pulp sensors that record temperature data every hour (Henning & Chetty, 2020e:6).

Containers must be pre-cooled prior to being loaded. It is advisable to turn the refrigeration system of the container on 12 hours before loading (Henning & Chetty, 2020e:9). A Genset is required to maintain the pre-cooling of the container before loading. During loading, the refrigeration system will be switched off and after loading, the Genset must be turned on for the refrigeration system to be switched on again (Henning & Chetty, 2020e:9).

Sensor number 1 must be inserted into the top layer of fruit on the top right corner of the first pallet loaded into the container on the left-hand side. Sensor number 2 must be inserted into the fruit of the pallet loaded in the middle of the container (pallet number 10) and the sensor must be placed close to the centre of the container at half the height of the palletised pallet. Sensor number 3 must be inserted into the fruit on the second-last pallet row from the door on the left-hand side, at half the height of the palletised pallet (pallet number 18) (Henning & Chetty, 2020e:6).

The on-board probe sensor positioning is indicated in Figure C10, to supply the reader with a visual illustration.

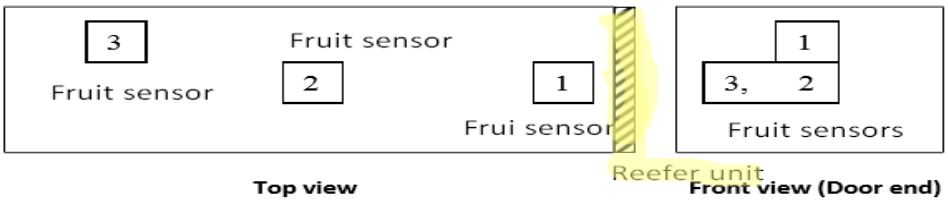

Figure C10: Sensor positioning in the container for Indonesia

Source: Henning and Chetty (2016:6)

Authorised PPECB technical personnel supervise the loading process and insert the on-board fruit sensors into the fruit as per special market protocol (Henning & Chetty, 2020e:10). A *Societe Generale de Surveillance SA* (SGS) inspector must also be present during the loading of table grapes to Indonesia. SGS will verify the quality, quantity and sealing of container (Sucofindo, 2018:2).

The temperature measured by the fruit on-board sensors may not exceed 2 °C for 14 days or 3 °C for 16 days, known as the on-board Sterilisation process. After 14 days with a pulp temperature below 2 °C or 16 days below 3 °C, the Steri protocol is completed and step-up temperature options may be considered by the exporter (Henning & Chetty, 2020e:5).

G. Taiwan

All fruit must be force-cooled to the target temperature of -0.5 °C at the cold storage facility where the container will be loaded, known as the land-base pre-cooling Steri process (PPECB, 2020:5). Before loading can take place, the cold storage facility must supply the authorised PPECB inspector with a physical printout of the fruit pulp temperature of the sensors. The PPECB inspector can request up to a 12-hour printout (Henning & Chetty, 2020d:3). Each forced-air cooling Steri tunnel must be equipped with a minimum of two pulp sensors on the inside of the tunnel and one pulp sensor on the outside of the tunnel (Henning, 2019b:5).

The container thermostat is set to control the delivery air at -1 °C with the vents of the container kept closed (PPECB, 2020:4).

Containers must be pre-cooled prior to being loaded. It is advisable to turn the refrigeration system of the container on 12 hours before loading (Henning & Chetty, 2020d:8). Three fruit pulp sensors must be used, the exporter has the option of three Sensitech spear probes or three on-board probe sensors (Henning & Chetty, 2020d:5).

A Sensitech spear probe is illustrated in Figure C11.

Figure C11: Sensitech spear probe
Photo credit, Researcher, 2020

The pre-cooling Sterilisation tunnel may only be open or breached when the authorised PPECB inspector gives the go-ahead to load the container. The pallets will be loaded directly from the tunnel to the container and loading must be completed within 40 minutes (Henning & Chetty, 2020d:8).

Sensor number 1 must be inserted into the fruit on the second layer from the top on the right-hand side of the last pallet loaded at the door on the left-hand side. Sensor number 2 must be inserted into the fruit on the second layer from the bottom of the last pallet loaded at the door on the left-hand side. Sensor number 3 must be inserted into the fruit on the second layer from the bottom of the last pallet loaded at the door on the right-hand side (Henning & Chetty, 2020d:5).

The on-board probe sensor or Sensitech spear probes, positioning is illustrated in Figure C12, to supply the reader with a visual illustration.

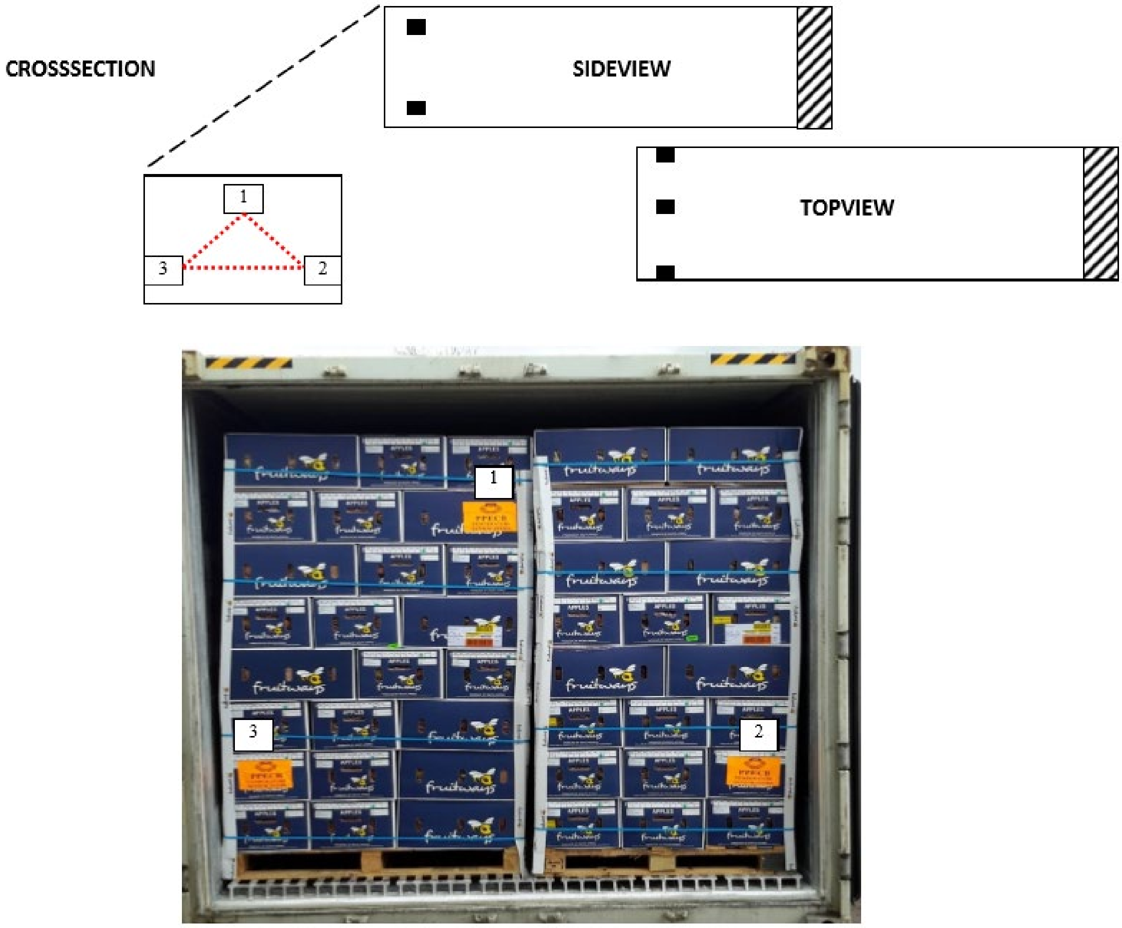

Figure C12: Sensor positioning in the container for Taiwan

Source: Henning and Chetty (2020f:6)

Authorised PPECB technical personnel supervise the loading process and insert the on-board fruit sensors into the fruit as per special market protocol. The tip of the sensor must not extend beyond the fruit (Henning & Chetty, 2020d:5).

The temperature measured by the fruit on-board sensors may not exceed 0.0 °C for 12 days, 1.67 °C for 14 days or 3.33 °C for 18 days known as the on-board Sterilisation process. After 12 days with a pulp temperature below 0.0 °C or after 14 days with a pulp temperature below 1.67 °C or after 18 days with a pulp temperature below 3.33 °C, the Sterilisation protocol is completed and step-up temperature options may be considered by the exporter (Henning & Chetty, 2020e:6).

H. Sri Lanka

All fruit must be force-cooled to the target temperature of -0.5 °C at the cold storage facility where the container will be loaded, known as the land-base pre-cooling Steri process (Henning & Chetty, 2019b:5). Before loading can take place, the cold storage facility must supply the authorised PPECB inspector with a physical printout of the fruit pulp temperature of the sensors. The PPECB inspector can request up to a 12-hour printout (Henning & Chetty, 2019b:5). Each forced-air cooling Steri tunnel must be equipped with a minimum of two pulp sensors on the inside of the tunnel and one pulp sensor on the outside of the tunnel (Henning & Chetty, 2018:5). The pre-cooling Steri tunnel may only be open or breached when the authorised PPECB inspector gives the go-ahead to load the container. The pallets will be loaded directly from the tunnel to the container and loading must be completed within 40 minutes (Henning & Chetty, 2019b:8).

The container thermostat is set to control the delivery air at -1 °C with the vents of the container kept closed (Henning & Chetty, 2019b:4). No on-board sensors will be installed into the container. Only the three sensors of the cold Sterilisation tunnel will be used (Henning & Chetty, 2019b:7). Two portable air temperature-monitoring devices are placed into the container (Henning & Chetty, 2019b:5).

The current portable air temperature monitoring devices used in the industry are illustrated in Figure C13.

Figure C13: Different portable air temperature monitoring devices used in the industry
Photo credit, Researcher, 2019

Portable air temperature monitoring device number one must be placed in the carton of the last pallet loaded on the left or right side of the container on the second layer from the bottom and in the centreline of the pallet. Portable air temperature monitoring device number two must be placed in the carton in the same pallet as device number one was placed in the container on the second layer from the top and in the centreline of the pallet (Henning & Chetty, 2019b:5).

The portable air temperature monitoring devices' positioning are indicated in Figure C14, to supply the reader with a visual illustration.

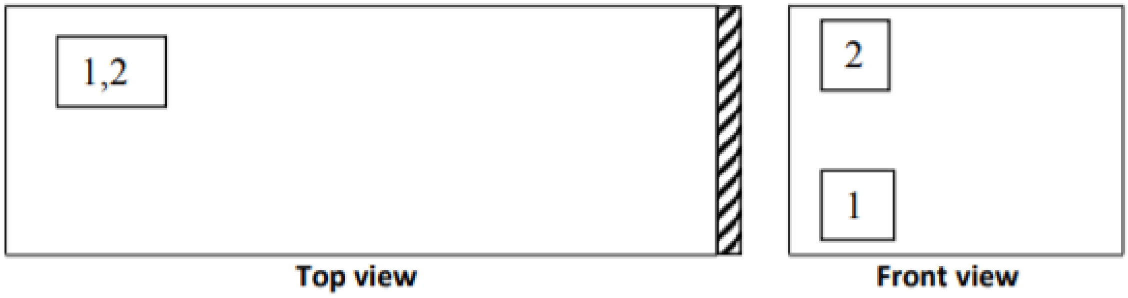

Figure C14: Sensor positioning in the container for Sri Lanka
Source: Henning and Chetty (2019b:6)

Authorised PPECB technical personnel supervise the loading process and insert the two portable monitoring devices (Henning & Chetty, 2019b:6).

The fruit pulp temperature may not exceed 0.0 °C for 14 days, 0.55 °C for 18 days, 1.1 °C for 20 days or 2.2 °C for 22 days, known as the on-board Sterilisation process. After 14 days with a pulp temperature below 0.0 °C, after 18 days with a pulp temperature below 0.55 °C, after 20 days with a pulp temperature below 1.1 °C or after 22 days with a pulp temperature below 2.2 °C, the Sterilisation protocol is completed and step-up temperature options may be considered by the exporter (Henning, 2019a:3)

IJ. Jordan

All fruit must be force-cooled to the target temperature of 0.0 °C at the cold storage facility where the container will be loaded, known as the land-base pre-cooling Steri process (Henning, 2019a:3). Before loading can take place, the cold storage facility must supply the authorised PPECB inspector with a physical printout of the fruit pulp temperature of the sensors. The PPECB inspector can request up to a 12-hour printout (Henning, 2019a:3) Each forced-air cooling Steri tunnel must be equipped with a minimum of two pulp sensors on the inside of the tunnel and one pulp sensor on the outside of the tunnel (Henning, 2019b:7). The pre-cooling Steri tunnel may only be open or breached when the authorised PPECB inspector gives the go-ahead to load the container. The pallets will be loaded directly from the tunnel to the container and loading must be completed within 40 minutes (Henning & Chetty, 2019a:8).

The container thermostat is set to control the delivery air at -0.5 °C with the vents of the container kept closed (Henning, 2019a:3). No on-board sensors will be installed into the container. Only the three sensors of the cold Sterilisation tunnel will be used (Henning & Chetty, 2019a:8). Two portable air temperature-monitoring devices are placed into the container (Henning & Chetty, 2019a:5).

Portable air temperature monitoring device number one must be placed in the carton on the first pallet loaded into the container on the left-hand side, on the top layer of the pallet. Portable air temperature monitoring device number two must be placed in the carton of the last pallet loaded into the container, on the second layer from the bottom of the pallet (Henning & Chetty, 2019a:5-6).

The portable air temperature monitoring devices positioning are indicated in Figure C15, to supply the reader with a visual illustration.

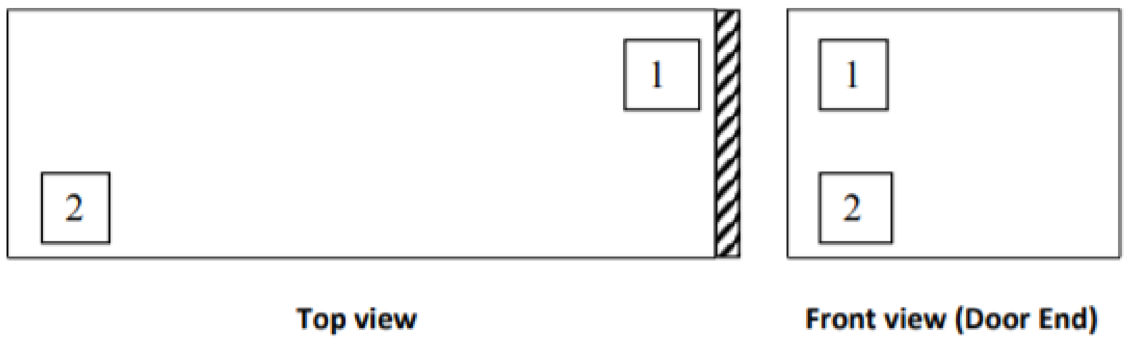

Figure C15: Sensor positioning in the container for Jordan
Source: Henning and Chetty (2019a:6)

Authorised PPECB technical personnel supervise the loading process and insert the two portable monitoring devices (Henning & Chetty, 2019a:6).

The fruit pulp temperature may not exceed 1.5 °C for 14 days. After 14 days, with a pulp temperature below 1.5 °C, the Sterilisation protocol is completed and step-up temperature options may be considered by the exporter (Henning, 2019a:3).